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The Effects Of Practice Under Conditions Of Contextual Interference On The Interjoint Kinematics Of Lifting

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THE EFFECTS OF PRACTICE UNDER
CONDITIONS OF CONTEXTUAL INTERFERENCE
ON THE INTERJOINT KINEMATICS OF LIFTING

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DEDICATION

This document is dedicated to parents, Ben and Brenda Stone,

whose belief in me has guided me through all endeavors,

and to

my husband, Keith,

who has been a constant source of support and encouragement,

and to

my children, Taylor and Stone,

my greatest inspiration and hope that all things are possible.

with love,

Beth Stone Norris

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ABSTRACT

THE EFFECTS OF PRACTICE UNDER CONDITIONS OF CONTEXTUAL INTERFERENCE ON THE INTERJOINT KINEMATICS OF LIFTING

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Purpose. The practice of exercises and functional tasks in a physical therapy session, typically involves the use of blocked practice schedules (low contextual interference, LCI), in which each variation of a task is practiced separately. Research has shown that the use of a blocked practice schedule results in superior acquisition performance, conversely, random practice (high contextual interference, HCI) results in enhanced retention and transfer of a motor skill (Magill and Hall, 1990). Lifting utilizing a squat technique is commonly practiced in orthopedic rehabilitation. The purpose of this study was to examine the effect of practice organization (HCI vs. LCI) on the starting posture and the relative timing between the hip and knee when lifting loads of increasing weights. **Methods.** Ten subjects, without history of low back pain and no experience with industrial lifting, were randomly assigned to either blocked or random practice groups. Reflective markers were attached to the lateral mallelous, lateral femoral condyle, greater trochanter, and inferior to the acromion process to define segment and joint angles of the knee and hip. Three dimensional motion analysis was performed while the subjects lifted a crate containing loads 15% to 75% of each subject's maximum dynamic lifting capacity (MDLC). Acquisition practice totaled 36 lifts with 12 trials at each load of 30%, 45% and 60% MDLC presented in either blocked or random order.

Two retention tests (post 15 minutes and post 7 days acquisition) of 3 trials at each practiced load were performed. Two transfer tests (15% and 75% MDLC) were given following the second retention test. Dependent variables for the hip and knee included: starting posture; angular excursion; midpoint difference; index of coordination and lift duration. Index of coordination was derived from the correlation between the hip and knee risetime difference (the difference in time required for the hip and the knee to competed 12%-88% of their total excursion) and midpoint difference (the difference in the time at which the hip and the knee complete 50% of their excursion). **Results.** Repeated measures analysis of variance found no significant difference between groups for the dependent variables. However, significance was found for the main effect of load during retention for lift duration (=.001), and knee excursion (p=.035), and during transfer for lift duration (p=.001), knee excursion (p=.040), hip excursion (p=.007), midpoint difference (p=.033) and index of coordination (p=.010).. **Conclusion/Implications.** Following this single practice session, performance in lifting technique was consistent between practice groups. Interestingly, at higher loads, subjects in both groups modified their lifting strategy to synchronize movement between the hip and knee. Further research is needed to assess the effects of multiple practice sessions under varied practice conditions in motor skill acquisition of lifting.

Chapter I

INTRODUCTION

The application of motor learning principles has been shown to effect the performance and learning of sports skills and the retraining of functional skills following neurological impairments. These principles include attaining meaningful goals and practice organization (Magill, 1998). In the arena of orthopedic rehabilitation, however, there has been little research regarding how the utilization of motor learning principles during treatment may affect the performance of functional tasks.

Motor learning distinguishes between the performance and the learning of a motor skill. An individual's performance can be assessed during the practice or acquisition of the motor skill, while, learning is assessed during retention and transfer tests (Jarus, 1994; Magill, 1998). Retention tests assess the ability of the leaner to perform the skill after a period of no practice. Transfer tests assess the ability of the learner to perform a skill that is novel in either context or variation to the skill that was practiced (Magill, 1998).

The influence of practice organization on motor learning has been the question of much research. Contextual interference refers to the "interference that results from practicing a task within the context of the practice situation" (Magill, 1998, p.230). A high degree of contextual interference results when several variations of a task are practiced in a random arrangement within the same session

(Magill, 1998). Practice under conditions of high contextual interference has been found to enhance retention and transfer of motor skills in both male and female subjects (Bortoli, Robazza, Durigon, & Carra, 1992; Hall, Domingues, & Cavazoes, 1994; Hanlon 1996; Landin & Hebert, 1997; Pollock ; Wegman 1999; Wisberg & Liu, 1991). In contrast, low contextual interference where the learner practices each variation of a task separately in a blocked practice schedule, results in superior acquisition performance (Magill and Hall, 1990). The phenomenon in which practice conditions of low contextual interference result in superior acquisition performance while practice conditions of high contextual interference result in enhanced retention and transfer of motor skills is known as the contextual interference (CI) effect (Magill and Hall, 1990).

The practice of exercises and functional tasks in a physical therapy session, however, typically involves the use of blocked practice schedules, or a low degree of contextual interference. Considering a primary objective of orthopedic rehabilitation to be the "remediation of functional limitation and disability" (American Physical Therapy Association, 1997, p. 1.8) as demonstrated by a patient's acquisition and retention of motor skills, a therapist might consider how the use of contextual interference for patients with orthopedic impairments may enhance the performance and learning of functional tasks.

Lifting is an example of a functional task that is commonly practiced in the rehabilitation of low back dysfunction. The teaching of this functional task often includes patient education and practice of lifting techniques that focus on utilizing a squat lift as opposed to a stoop lift. A stoop lift is initiated with the knees extended and the trunk flexed. In contrast, a squat lift begins with the knees flexed and a vertical trunk (Trafimow, Schipplein, Novak, and Andersson, 1993). While research is inconclusive in supporting a squat lift over a stoop lift for the means of preventing low back injury (van Dieen, Hoozemans & Toussaint, 1999), there are mechanical advantages of a squat technique over a stoop technique. Burgess-Limerick, Shemmell, Barry, Carson and Abernethy (2001) describe the advantage of a squat posture as allowing "a functional distal-to-proximal pattern of inter-joint coordination" (p.560) between the knee, hips and trunk, which delays rapid shortening of the hamstrings and rapid shortening of the erector spinae. The delay in rapid shortening of the hamstrings and erector spinae has the biomechanical advantage of increasing the muscle's strength "early in the extension phase when the acceleration of the load is the greatest" (p.560).

Boston, Rudy, Mercer and Kubinski (1993) define the coordination between body joints during a lift as "the relative timing of the motion of one joint with respect to the other" (p. 139). During the performance of a lifting task utilizing either a squat or stoop technique, the extension phase (lifting of the load) occurs with distal to proximal interjoint coordination, while the flexion phase (lowering of the load) involves proximal to distal joint coordination (Burgess-Limerick, Abernethy, & Neal, 1993). Thus, as a load is lifted, knee extension leads hip extension, which leads trunk extension.

Research has shown that as a load increases there is a delay in the distal to proximal interjoint coordination during the extension phase of the lift, and the lifting technique becomes more of a stoop, independent of the subject's initial posture (squat or stoop) at the onset of the lift (Burgess-Limerick, Abernathy, & Neal, 1993; Burgess-Limerick, Abernethy, Neal, & Kippers, 1995; Scholz, 1993; Scholz, Millford, & McMillan, 1995). Research has also been conducted to examine the lifting patterns of individuals with low back pain (Boston el at, 1993; Boston, Rudy, Lieber, and Stacey, 1995; and Lieber, Rudy, Boston, 2000). Control subjects utilized a movement pattern in which the knee and hip completed the lifting movement at the same time, while, in subjects with low back pain, the hip and knee completed the movement at different times (Boston et al., 1993). Further research found that the movement pattern of subjects with low back pain was similar to that of control subjects after a 3 ½ week pain rehabilitation program (Boston et al., 1995) and after body mechanics instruction (Lieber et al., 2000).

A desired outcome of lifting practice in a physical therapy treatment session is the ability of the patient to perform a lifting task utilizing a squat technique (or "leg lift"). In addition to patient education regarding the mechanics and benefits of lifting with a squat technique, the therapist typically organizes the practice session to involve repetitive lifting of loads of one weight followed by repetitively lifting of loads of a second weight, using a blocked practice schedule. A major assumption of the physical therapist is that the patient will continue to utilize the squat technique when lifting a variety of loads beyond the conclusion of the treatment session. Since previous research has shown that increasing the load will result in a delay in distal to proximal coordination of joint movement, thus changing the lifting technique from a squat lift to a stoop lift, the question arises whether a person can learn to utilize a squat technique even when lifting heavy loads? Because a random practice schedule (high contextual interference) has been shown to enhance the retention and transfer of a motor skill, this practice method might facilitate retention of the learned squat technique under increasing loads with synchronous movement between the hip and knee.

Problem Statement

The purpose of this study is to examine the effect of practice organization using conditions of high or low contextual interference on the starting posture, and relative timing of the hip and knee, expressed as the hip-knee index of coordination and the hip-knee midpoint difference, as subjects lift loads of increasing weights.

Definitions

Acquisition

Performance of a motor task that occurs during practice of the task.

Contextual Interference

The interference that results when more than one variation of a task is practiced in one session (Magill & Hall, 1990).

Dynamometer

An instrument that measures static lifting ability in units of pounds. In this investigation, a subject will exert maximal effort against a dynamometer to obtain a measure of maximal static lifting capacity prior to initiating acquisition practice.

Generalized Motor Program

A memory representation of a movement class of actions, distinguished by invariant characteristics (Schmidt, 1988).

High Contextual Interference

Practice of all variations of a task in which the task variations are presented in random order, excluding the practice of one task variation two consecutive times (Magill & Hall, 1990; Magill, 1998).

Hip-knee midpoint difference

The difference between the hip midpoint and the knee midpoint. A zero difference indicates that the hip and knee have reached their midpoint at the same time. A negative difference indicates that the hip reaches its midpoint before the knee, while a positive difference indicates that the knee reaches its midpoint before the hip (Boston et al., 1993). A small absolute value of the midpoint difference indicates increased synchronization between the hip and knee in which the hip and knee are reaching their midpoints close to the same time.

Hip-knee Risetime Difference

The difference between the hip risetime and the knee risetime. A positive difference indicates that the knee is completing its angular excursion faster than the hip. A negative difference indicates that the hip is completing its angular excursion faster than the knee (Boston et al., 1995).

Index of Coordination

The correlation between the hip-knee midpoint difference and the hip-knee risetime difference, describing the synchrony between the hip and knee during the lifting movement. A negative index of coordination indicates synchronized movement in which the hip and knee complete the lift together. A positive index of coordination indicates asynchronous movement in which the hip and knee do not complete the movement together (Boston et al., 1995).

Invarient Features

The characteristics of a generalized motor program that are fixed from one performance of a movement skill to another (Magill, 1998).

Leg Lift

The starting posture of a lifting movement in which the difference between the hip and knee angles at the start of the lift is between 0° to 55° (Lieber et al., 2000).

Low Contextual Interference

Practice of one variation of a task is completed before initiating practice of another variation of the task (Magill & Hall, 1990; Magill, 1998).

Maximal Dynamic Lifting Capacity (MDLC)

A derived estimation of the maximal weight a subject can lift from the ground to waist height. The estimation is derived from 30% of the subject's maximal static lifting capacity.

Midpoint

The time from the beginning of the extension phase of the lift at which the hip or knee has completed 50% of its angular excursion. The time is normalized by the total duration of the lift, thus, representing the proportion of the total lift duration required to complete 50% angular excursion (Boston et al., 1995).

Parameters

Variant features of a generalized motor program that can be modified without changing the generalized motor program. These variant features include overall force and overall duration.

Retention

The assessment of learning a practiced skill that occurs after a time period following the conclusion of practice (Magill, 1998).

Risetime

The time, normalized by the total lift duration, required for the hip or knee to complete 12% to 88% of its joint excursion from a position of joint flexion to joint extension (Boston et al., 1995).

Squat Lift

The starting posture of a lifting movement in which the knees and hips are flexed and the trunk is maintained in an upright, extended position (Trafimow et al., 1993). A negative difference between hip and knee starting angle indicates a squat lift (Lieber et al., 2000).

Starting Posture

The difference between the hip and knee angles at movement onset of the lifting task.

Stoop Lift

The performance of a lifting movement with the knees extended and the trunk and hips flexed (Trafimow et al., 1993). A positive difference (> 60°) between hip and knee starting posture indicates a stoop lift (Lieber et al., 2000).

Transfer

An assessment of learning involving the performance of a skill that is different from the practiced skill (Magill, 1998).

Hypotheses

The following hypotheses will be tested in this investigation involving subjects practicing under conditions of high contextual interference and conditions of low contextual interference:

1. During acquisition across all loads, there will be no significant difference in the starting posture, hip-knee midpoint difference and index of coordination for subjects practicing under conditions of high or low contextual interference.
2. During retention and transfer tests across all loads, the starting posture for subjects practicing under conditions of high contextual interference will be

significantly less positive than the starting posture of subjects practicing under conditions of low contextual interference.

3. During retention and transfer tests across all loads, the hip-knee midpoint difference for subjects practicing under conditions of low contextual interference will be significantly greater than the hip-knee midpoint difference of subjects practicing under conditions of high contextual interference.

4. During retention and transfer tests across all loads, the index of coordination will be significantly more negative for subjects practicing under conditions of high contextual interference than the index of coordination for subjects practicing under conditions of low contextual interference.

Rationale

The studies by Bortoli et al. (1992), Hall el al. (1994), Hanlon (1996), and Wisberg and Liu (1992) suggest that the retention and transfer of a motor skill is enhanced when practiced is conducted under conditions of high contextual interference. Lifting is a common motor skill practiced in orthopedic rehabilitation with the goal that the client will utilize a squat lifting technique beyond the context of the treatment session and under task variations of increasing loads. Research regarding the kinematics of lifting, has found a delay in the distal to proximal interjoint coordination of the knee, hip and trunk as the load to be lifted is increased, thus, resulting in the lifting technique that becomes more of a stoop lift (Burgess-

Limerick et al., 1993; Burgess-Limerick et al., 1995; Scholz, 1993; Scholz et al., 1995). Boston et al 1995 found that a pain rehabilitation program was effective in changing the lifting movement employeed by subjects with low back pain to that similar of control subjects. Additionally, Lieber et al (2000) reported that rehabilitation consisting of intensive body mechanics instruction resulted in a change in initial lifting posture to that of a squat posture and improved synchrony between the hip and knee joints during the lifting movement. This research study suggests that a client's lifting technique may be affected by practice involving body mechanics instruction.

The results of this study will contribute to the body of knowledge concerning the effects of contextual interference by investigating how the organization of practice affects motor skill learning of a task used in physical therapy treatment sessions. This will assist therapists in determining the most effective method to organize practice to enhance learning of the functional task of lifting. An additional component of this research will be to determine how two different practice schedules, blocked and random, affect the kinematics of lifting.

Chapter II

REVIEW OF THE LITERATURE

This study is designed to investigate the effects of practice under conditions of high and low contextual interference on the interjoint kinematics of lifting. This study involves a functional task and does not attempt to discern if the task variations created by lifting varying loads result in movements governed by the same or different GMPs. The review of literature is divided into three sections. In the first section, the interaction of task characteristics with the CI effect is presented with considerations of: 1) real-life tasks practiced under conditions of contextual interference; and 2) the influence of same and different generalized motor programs. The second section presents CI research involving learner characteristics consisting of: 1) skill and experience; and 2) subject population. The third section contains a discussion of research involving the interjoint kinematics of lifting.

Task Characteristics

Real-life tasks

Real-life tasks include tasks performed in the field as well as functional tasks performed in the laboratory. At the time of the Magill & Hall (1990) review on the CI effect, there were only two studies involving real-life tasks. Support for the CI effect, therefore, was primarily based on the findings of laboratory research tasks. Without research support, generalizing laboratory findings of the CI effect to field or applied settings where motor skills are taught, practiced for sporting events, or relearned during rehabilitation may not result in the expected findings of enhanced skill learning when practice conditions involve high interference conditions. Since 1990, there has been more research on the CI effect involving real-life tasks. Research supporting the CI effect has included task variations of volleyball serves (Bortoli et al., 1992), baseball batting (Hall, Domingues & Cavazoes, 1994), functional reaching (Hanlon, 1996), basketball (Landin & Hebert, 1997), frisbee toss (Pinto-Zipp, 1996), racquet striking (Wegman, 1999), and badminton serves (Wrisberg & Liu, 1991). In contrast, the CI effect was not found in research involving golf shots (Brady, 1997), putting (Goodwin et al. 1996), tennis (Hebert, 1996), and beanbag toss (Jarus & Goverover, 1999).

Hall et al. (1994) utilized skilled baseball players to investigate the effects of blocked and random practice conditions of hitting baseballs thrown in three different variations; fastballs, curveballs, and change-ups. Practice occurred twice a week over six weeks, with 15 trials of each pitch practiced per session. The subjects were 30 male baseball players with an average of 9.5 years of experience in competitive baseball. The subjects were divided into three practice groups: 1) random; 2) blocked; and 3) control. The practice sessions were in actuality an additional two sessions to the weekly practice schedule. Thus, the control group participated in the regular practice, but did not receive the additional two sessions per week. The goal was the performance of a "solid hit", and acquisition performance was assessed on the 5^{th} and 8^{th} practice sessions. At the conclusion of the 6 weeks, learning was assessed in two transfer tests in which the transfer condition was either blocked or random presentation of the same pitch variations. Random practice conditions resulted in higher scores on both transfer tests as compared to the blocked practice condition and control group. The blocked practice condition resulted in higher scores than the control group on both transfer tests. The researchers concluded that the CI effect "is not simply an early learning or laboratory-based learning phenomenon" (p. 840). Thus, the results of this research show that practice under conditions of high contextual interference improves learning of motor skills in a field setting for subjects with an initial high skill level. The authors also state that the motor skill of batting is appropriate for random practice in that the batter does not know what type of pitch will occur in an actual game situation.

Partial support of the CI effect in the task of volleyball was found by Bortoli et al. (1992) when three different volleyball skills (volley, bump and serve) were practiced in blocked, random, serial, or high interference serial orders. Fifty-two 9th grade students participated in six weekly practice sessions. In each session, 36 repetitions were performed in an order specific to the practice group. Each skill was practiced 72 times over the six sessions. One week following the last practice session, a retention test was given along with two transfer tests. The transfer tests consisted of performing each skill at a distance 1 meter shorter than in acquisition (short transfer) and 1 meter longer than in acquisition (long transfer). There were no differences between the groups in acquisition, retention, short transfer, and long transfer except for the serving skill. For the long transfer, subjects practicing under random and serial practice performed the serving skill better than subjects in the blocked group and serial with very high interference group. The authors note that the difficulty level increased from the short transfer to the retention test to the long transfer. Since differences between the groups were not evident except in the serving skill during the long transfer test, the authors suggest that the difficulty of the other test conditions was not enough to distinguish skill differences between practice groups. The authors state that "more frequent sessions would be necessary to improve significant learning" (p.561) once a certain performance level had been attained. It should also be noted that the practice schedule for the random group consisted of the performance of six practice trials of one skill before practicing the next skill, with the skills presented in random order. This arrangement resembles repetition practice and could contribute to the findings of no CI effect for random practice as is defined in this study.

The CI effect was not found in research involving variations of golf skills (Brady, 1996), golf putting (Goodwin& Meeuwsen, 1996), tennis strokes (Hebert et al., 1996), or beanbag toss (Jarus & Goverover, 1999). Brady (1996) compared random and blocked practice conditions of four variations of golf skills. Practice was conducted over 12 instructional sessions in which 15 trials of each skill were practiced by college age students. Subjects were allowed to select the club used for each shot as well as the target distance. Learning was assessed by measuring the total number of shots required to complete 18 holes of golf played one week following the last practice session. While the benefit of random practice was not reported, the authors note uncontrolled variables including the skills practiced during acquisition, the prior skill level of the subjects, the skills assessed during transfer and the amount of feedback provided.

In an investigation of the interaction of skill ability on practice schedule variations involving tennis forehand and backhand strokes, Hebert et al. (1996) found blocked practice conditions more beneficial than alternate practice for low skilled students when the strokes were assessed in a post-test. For the high skilled students, there was no significant difference in the post-test scores when practice was performed under blocked or alternate conditions.

Non-laboratory tasks involving children as subjects resulted in conflicting findings regarding the CI effect. Jarus & Goverover (1999), Pinto-Zipp (1996), and Pollock & Lee (1997) compared children and adults practicing non-laboratory tasks under blocked or random practice conditions. Under higher acquisition conditions (81 verses 54) Pinto-Zipp reported improved accuracy for throwing a frisbee to targets of varying distances in the immediate and delayed retention tests for adults practicing under random conditions. Likewise, in the study by Pollock & Lee (1997), adults practicing a ballistic aiming task under random conditions demonstrated superior retention and transfer performance as compared to adults practicing under blocked conditions. For children, the benefit of random practice was not found by Pinto-Zipp (1996) in retention or transfer tests. Jarus & Goverover (1999) reported similar findings for 5 and 11 year olds performing a beanbag toss. For 7 year-olds, however, Jarus and Goverover found blocked and combined blocked/random practice to be more beneficial in acquisition and retention. Although acquisition performance did not differ between children, age 7 years, practicing under blocked or random conditions in the study by Pollock & Lee (1997), random practice was superior to blocked practice during both retention and transfer.

Same and different generalized motor programs

Contextual interference (CI) is produced when more than one variation of a task is performed within one practice session. Determining whether the CI effect occurs when task variations are of the same or different generalized motor program (GMP) has received much consideration. A generalized motor program is defined as a "memory-based representation of a class of actions with each class defined by invariant features" (p. 41, Magill, 1998). Invariant features of a GMP include relative timing and relative force. When movement tasks involve variations of relative timing and/or relative force, the resultant movements are said to be controlled by different GMP. Alternately, absolute force and overall duration are examples of variant features or parameters of a GMP that can be modified without changing the GMP (Magill, 1998).

Magill and Hall (1990) proposed a hypothesis that the CI effect would occur for tasks variations that are governed by different GMPs, but not for task variations of the same GMP. Thus, according to the Magill and Hall (1990) hypothesis, the conditions of high contextual interference created by a random practice schedule would enhance learning of movement skills governed by different GMPs. However, when the parameters of a GMP are modified to produce task variations of the same GMP, the CI effect would not be found.

Magill and Hall's hypothesis has been investigated through both laboratory based research (Pollatou, Kioumourtzoglou, Agelousis, & Mavromatis,1997; Sekiya, Magill, Sidaway, & Anderson, 1994; Sekiya, Magill, & Anderson, 1996; Shea, Kohl, & Indermill, 1990; Sherwood, 1996) and non-laboratory involving functional tasks (Bortoli, Robaza, Durigon, & Carra, 1992; Brady, 1996; Goodwin & Meeuwsen, 1996; Hebert, Landin, & Solmon, 1996; Landin & Hebert, 1997; Pollock & Lee, 1997; Wegman, 1999; and Wrisberg & Liu,1991).

In laboratory structured research, the benefits of high interference, random practice, for movement tasks governed by the same GMP has been found by Sekiya et al. (1994), Sekiya et al. (1996), Shea et al. (1990), Sherwood (1996). The CI effect was not demonstrated for task variations involving different GMPs in studies by Pollatou et al. (1997), Sekiya et al. (1994) and Sekiya et al. (1996).

Sekiya et al. (1994) utilized a tapping task with three variations of relative movement time and overall movement time to produce GMP learning and parameter modifications of different GMPs, respectively. 36 subjects performed 270 acquisition trials (90 for each variation) under either blocked or serial random conditions with knowledge of results (KR) provided after each trial. A retention test was conducted 24 hours after acquisition. When movement variations involved changes in the relative movement time (GMP learning), the CI effect was not demonstrated. However, when practice involved parameter modifications of different GMPs, parameter learning was enhanced by random practice. In a second experiment, the CI effect was found when practice involved learning parameter modifications of the same GMP. The researchers concluded that the CI effect was evident with parameter learning, not learning of GMP. Sekiya et al. (1994) suggest a modification to the Magill and Hall (1990) hypothesis in which "the CI effect will be found in parameter learning, but not in GMP learning, regardless of whether skill variations are controlled by the same of different GMPs" (p. 337). The CI effect for parameter learning of the same GMP was also investigated by Sekiya et al. (1996) using the task variation of overall movement force. The results of this study support the benefit of high contextual interference, random practice, in learning overall force parameter modifications.

Pollatou el al. (1997) investigated which practice schedule (blocked, random, or serial) is most beneficial when learning motor skills that are controlled by different GMPs. 66 undergraduate students, 30 males and 33 females, were divided into three practice groups to learn the novel tasks that simulated kicking and throwing. The practice groups were blocked, random, and serial. The subjects practiced the tasks 4 days a week for 2 weeks. A retention test was given 1 week following the completion of acquisition. Pollatou et al. (1997) found no difference in acquisition performance between the three groups or in the retention test with the exception of the throwing task, for which subjects in the random practice group had better retention performance. These findings apply to the field of physical education in which motor skills of different motor programs must be taught within the same teaching unit. The researchers concluded that when motor skills involving different GMPs must be learned in the same teaching unit, random, blocked or serial practice would be equally effective in learning of the skills.

In other laboratory-based research, Shea et al. (1990) and Sherwood (1996) reported the benefit of random practice in the learning of motor skills governed by the same GMP. After completion of 400 acquisition trials, Shea et al. found random practice superior in the learning of overall force modification during retention and transfer tests. Likewise, in an investigation of rapid reversal movements performed at three different amplitudes, Sherwood found blocked practice to be superior in acquisition performance, while random practice was superior in an immediate retention test.

In a non-laboratory research setting, Pollock & Lee (1997) report the CI effect in the learning of parameter modifications of the same GMP involving variations of the overall force in a ballistic aiming task. Pollock and Lee (1997) investigated 24 seven year olds and 24 adults performing a task that was a modified version of the game Crokinole. The task involved using the middle finger to propel a 3 cm diameter wooden disc toward 1 of 2 bumper targets of varying length. These targets, when struck, would rebound the disc toward or into the goal target, a 4 cm diameter hole. 90 acquisition trials were performed by all subjects, followed by two transfer tests, and a retention test. Each transfer test consisted of 10 trials presented in blocked order and involved the use of a new bumper. The retention test consisted of 15 randomly organized trials using the initial 3 bumpers.

Acquisition performance was superior for adults practicing under blocked conditions. As might be expected, adults performed better than the children independent of practice condition. For the children, however, there was no difference in acquisition performance between the blocked and random groups. Both children and adults practicing under random conditions performed better during the retention test and the two transfer tests than the children and adults practicing under blocked conditions. Thus, enhanced learning of the motor skill was found for children as well as adults who practiced under random conditions. Additionally, for children, random practice did not result in reduced acquisition performance.

Similar findings were reported by Landin & Hebert (1997) for the basketball set shot, and Wrisberg & Liu (1991) for badminton serves. Using subjects with 2 years of basketball experience, Landin & Hebert found moderate CI practice to be more beneficial in the retention of the basketball set shot. The learning of this motor skill occurred without the difference in acquisition performance between low CI, moderate CI, and high CI practice conditions.

Wrisberg & Liu investigated blocked verses alternate practice conditions in the learning of short and long badminton serves by college-aged subjects inexperienced in the skill of badminton. Alternate practice involved alternating between a short serve and a long serve. There was no difference between groups for the acquisition, retention, and transfer of the long serve. However, acquisition performance of the short serve was superior in the blocked practice group, while retention and transfer was superior in the alternate practice group. Through these two studies, Landin & Hebert and Wrisberg & Liu demonstrate the benefit of moderate CI and alternate practice, respectively, which are between the extremes of low CI and high CI practice conditions.

In contrast to the findings of Pollock and Lee (1997), Goodwin et al. (1996) did not find random practice beneficial in the learning of overall force modifications necessary to successfully putt a golf ball various distances. 30 female students (mean age 26.2 years) practiced putting golf balls under one of three practice conditions: 1) random; 3) blocked-random; and 3) blocked. In each practice condition, 33 practice puts were performed to each of three putting distances (2.43 m, 3.95 m, 5.47 m), totaling 99 trials. Practice was conducted over two days for a total of 198 acquisition trials. 24 hours following the second practice day, 30 retention trials were performed and 30 transfer trials were performed to three new distances (1.67 m, 3.19 m, 6.23 m). Both retention and transfer were performed in a blocked sequence. There was no difference in acquisition performance or retention between the three groups. Blocked-random and random groups performed better at the 6.23 m distance during transfer with no difference between the three groups at the 1.67 m and 3.19 m distances. Goodwin and Meeuwsen (1996) conclude in support of the Magill and Hall hypothesis that the contextual interference effect would not be found when task variations involve parameter modification of a GMP.

In a study by Wegman (1999) 54 fourth grade girls practiced three motor skills governed by different GMPs: ball rolling; racket striking; and ball kicking. Ball rolling and racquet striking were skills with which the subjects had previous experience, while ball kicking was considered a novel skill that the subjects had not practiced in previous physical education classes. The subjects were divided into three groups; 1) repetitions (blocked), 2) random; and 3) combined. Practice occurred in one physical education session and consisted of 13 trials of each skill. A retention test was given 3 weeks following practice. Wegman reports that all subjects improved during practice with the repetitions group performing better than the other two practice groups. During the retention test, there was no difference between the three groups in performance of the ball rolling or ball kicking skills. However, the random group performed the racquet striking skill better than the repetitions group or the combined group. Wegman suggests that the CI effect found for the racquet skill may be attributed to the fact that this skill is an open skill and one that the subjects had previous experience with. An open skill is performed in a non-stable environment, creating a more difficult learning situation which enhances the amount of contextual interference than a closed skill in which the environment is stable (Magill, 1998).

The hypothesis presented by Magill and Hall (1990) that the CI effect would only occur when task variations of different GMP were practiced was not supported by the findings of Brady (1996) with the practice of four different golf shots; Bortoli et al. (1992) in the accuracy of three different volleyball skills; Hebert et al. (1996) comparing tennis forehand and backhand strokes practiced under random or blocked conditions; Pollatou (1997) with the practice of a throwing skill and a kicking skill. The finding that random practice did not benefit the learning of the above sport skills may be due to task variations each involving a different movement sequence and muscle recruitment in addition to variations of relative force or timing. The amount of interference contained in the practice of these skill variations may have exceeded the level of interference that is optimal for enhancing learning.

The current research study involves the analysis of the interjoint coordination between the hip and knee under practice conditions of high and low contextual interference in which the load to be lifted is varied. This load variation creates changes in the overall force necessary to perform the lifting task, which, according to Magill (1998), is a parameter modification of the same GMP. However, research has found that as the load to be lifted is increased, there is a change in the relative timing of the motion of one joint with respect to another (Burgess-Limerick et al., 1993, 1995; Scholz, 1993; and Scholz et al., 1995), possibly creating task variations controlled by different GMPS. While, the lifting task contained in this investigation involves practice of a parameter modification (a change in the overall force created by load variations), this investigation is not intended to examine the Magill and Hall (1990) hypothesis, but to examine the effects of practice under conditions of high and low contextual interference on the relative timing between the hip and knee.

Learner Characteristics

Skill and experience

It has been suggested that subjects in the early stage of learning may benefit from a practice schedule of low contextual interference until experience with the skill is established (Magill and Hall, 1990). To investigate this theory, research has been conducted comparing conditions of low and high interference early in practice, as well as, comparing the CI effect for low and high skilled subjects.

Shea, Kohl and Indermill (1990) investigated the interaction of the CI and amount of practice by performing blocked and random retention tests after 50, 200 and 400 practice trials. The task practiced was dynamic force production of five target forces. Under random retention conditions after 50 practice trials, subjects who practiced under blocked conditions demonstrated less error than subjects who practiced under random conditions. Under blocked retention conditions, both random and blocked practice groups performed similarly until practice trials reached 400. The benefit of random practice (assessed with random retention test) was not demonstrated until the completion of 400 trials. The researchers suggest that the early benefit of blocked practice (50 trials) may be associated with subjects being in the early stage of learning where a blocked practice schedule provides the establishment of experience with the skill through practice repetition.

Del Rey (1989) conducted an experiment to determine if a subject's level of experience with an open sport skill would affect performance on laboratory tasks also characterized as open skills. 64 subjects performed acquisition practice of a Bassin Anticipation Timer task in either blocked or random presentation. A retention test was given one minute following the conclusion of acquisition practice where half of the subjects were tested under random retention context and half under blocked retention context. The results of this retention test indicated that subjects practicing under random conditions had superior retention performance as compared to subjects practicing under blocked conditions, when retention was assessed under both blocked and random conditions. 32 subjects then received training on the open sport skill of tennis consisting of twice weekly sessions for four weeks. At the conclusion of the tennis training, all subjects participated in a second retention test and a transfer test involving two new velocities of the timing task. The subjects who received tennis training and participated in random acquisition practice and retention conditions had less variable error than untrained subjects who participated in random acquisition and retention conditions. There was no significant difference in retention or transfer for untrained subjects who practiced under either blocked or random acquisition conditions. Based on these research findings, Del Rey suggests that prior experience with an open sport skill will facilitate the retention and transfer of laboratory based motor skills requiring similar processing when these skills are practiced under high contextual interference conditions.

While the above research has involved novice subjects inexperienced with the task being practiced, Hall et al. (1994) investigated the CI effect for skilled baseball players. Random practice proved more beneficial than blocked practice in improving batting accuracy with three variations of pitches.

Hebert et al. (1996), however, reported findings contradictory to those of Hall et al. (1994). Hebert et al. (1996) classified subjects as low and high skilled based upon a subjective questionnaire and results of a tennis achievement test. The subjects were further divided into two experimental groups that practiced forehand and backhand strokes under low (blocked) or high (alternate) contextual interference conditions. Practice was conducted over 9 sessions in which 15 strokes of each skill were performed. On a post-test achievement assessment conducted under both blocked and alternate schedules, low skilled subjects that practiced under blocked conditions had better retention scores than those who practiced under random conditions. For the high skilled subjects, there was no significant difference in practice condition. These results support the authors' prediction that low skill subjects would have enhanced learning when practicing under conditions of low contextual interference. For high skilled subjects, however, conditions of high contextual interference did not enhance learning. Herbert et al. (1996) suggest that this could be due to a lack of sufficient interference created by alternating between forehand and backhand strokes to reduce acquisition performance yet enhance retention or learning. The differing results between the studies by Hall et al. and Hebert et al. could be in each author's definition of skill level. Hall et al. utilized collegiate baseball players, where as, Hebert et al. defined the skill of the subjects based on self- report. It could be that the subjects in the study by Hebert et al. were not at the skill level to benefit from conditions of high contextual interference.

Landin & Hebert (1997) studied the effects of low (blocked practice), moderate (combined blocked-random practice) and high CI (random practice) on the basketball set shot from 6 positions. Subjects were college-aged with 2 years of high school basketball experience. Practice occurred over 3 days in which the subjects performed 30 trials per day. One day following the last practice session, a retention test was given. The retention test involved 12 trials from three of the six positions presented in blocked order, 12 trials to the same three positions presented in serial order, and 10 trials of a free-throw shot. All groups improved during acquisition with no difference between groups on performance. During retention, the moderate CI group achieved higher scores than the low CI or high CI, between which there was no difference. The researchers suggest that in an applied setting, moderate CI may be most beneficial for learning since environmental factors cannot be controlled and may contribute to increasing difficulty associated with high CI practice. Additionally, the authors note that while the subjects were experienced, they were not 'elite' athletes in the sport of basketball and that experience level varied among subjects. Landin & Hebert conclude that CI "along the continuum rather than the extremes" (p.360) may be more beneficial in an applied setting where a range of skill levels may be present.

Subject populations

While the interaction of the CI effect with subject characteristics of age, skill, experience and gender has been investigated, there has been little research involving the CI effect for physically impaired individuals practicing a functional task in the relearning of a motor skill. The reviewer found only one research study pertaining to subject characteristics of this type.

Hanlon (1996) conducted a study to assess "the differential effects of style of practice on the retention of a functionally oriented movement sequence with hemiparetic patients" (p. 811). 24 subjects post unilateral cerebral stroke (mean onset time of 34 months) were divided into 3 groups based on practice conditions; random, blocked and control. The task consisted of 5 steps: "open a cupboard door, grasp a coffee cup by the handle, lift the cup off its shelf, place the cup on a counter, and release the grasp" (812). Criterion performance for acquisition was successful completion of 3 consecutive trials of the task. Blocked practiced involved 10 trials per day until the criterion was attained. Random practice involved 2 sets of 5 trials per day. During random practice, interference was created by alternating each trial of the movement sequence with pointing, touching objects or touching specific spots. The control group received no practice of any task. A retention test of the movement sequence was conducted 2 and 7 days following attainment of the criterion. Retention learning was superior for subjects practicing under high CI conditions. Additionally, there was no difference between random and blocked practice for the number of acquisition trials necessary to achieve criterion performance or on the mean time to complete the successful trials.

The results of this study present a broadening of the CI effect from motor skill learning of sport skills to motor skill learning for the retraining of function. Continuing research of the CI effect in the field of rehabilitation with consideration of tasks and subject characteristics would benefit the further understanding of motor learning.

Interjoint Kinematics of Lifting

Lifting is a commonly included materials handling component of many job descriptions. Despite efforts to promote safe lifting practices, a high occurrence of injury related to workplace lifting tasks persists. To better determine what might constitute safe lifting practices, research has been conducted on the kinematics of lifting when task variations are imposed. These task variations have included the method (squat or stoop); changes in load magnitude; and the speed of lifting.

There are two predominant methods of lifting technique; the stoop lift, and the squat lift (Toussaint, van Basa, van Langen, de Looze, and van Dieen, 1992). Each method is characterized by the initial starting posture. The stoop lift, also referred to as a back lift, is initiated with knee extension and trunk flexion. In contrast, the squat lift, or leg lift, begins with knee flexion and a vertical trunk (Trafimow, Schipplein, Novak, and Andersson, 1993). While a few studies have compared the two methods of lifting, most studies have either allowed a free-style technique or specified a specific starting posture when investigating the effect of task variations on lifting performance. Kinematic variables such as joint angular excursion, joint angular velocity, and angular acceleration have been examined to quantify lifting performance. More recently, research has included qualitative information such as phase-plane plots and quantification of the relative timing between joints through relative phase angle (Burgess-Limerick, Abernathy, & Neal, 1993; Burgess-Limerick, Abernethy, Neal & Kippers, 1995;, Scholz, 1993; Scholz, Millford, & McMillan, 1995) and index of coordination (Boston et al. 1993, 1995; Leiber et al. 2000).

Kjellberg et al. (1998) conducted one of the few studies that directly compared the two methods of lifting, defined as a back lift and a leg lift. The study involved 12 women lifting a 8.7 kg box from the floor (handles were 25 cm from the floor) using the two methods and two lifting speeds; fast (1 second) and slow (2 seconds). Five trials were performed with each method and speed. Body movements were recorded using a kinematic analysis system and EMG. Trunk angular displacement and velocity was significantly higher with the back lift, while peak trunk angular velocity and acceleration was higher during fast lifts. Due to the greater inter-subject variability for all kinematic and EMG variables when lifting was performed using a leg lift technique, the authors question "the use of averaged subject data for evaluating work technique" and instead suggest examining "the performance and movement pattern of the individual worker" (p. 814).

Burgess-Limerick et al. (1993) demonstrated the use of phase plane qualitative analysis of lifting in a case study of a subject lifting a 8.5 kg mass using a free-style technique. Through the use of an angle-angle plot of hip angular position over knee angular position, the authors describe an in-phase coordination of the hip and knee with flexion occurring simultaneously at both joints. To further expand upon this coordination between distal and proximal joints, Burgess-Limerick et al. (1993) utilized a phase plane diagram of normalized angular velocity over normalized angular position. The relative phase angle of one joint was then compared to another. Through the use of relative phase angles, Burgess-Limerick et al. (1993) determined that the flexion phase of lifting occurred with proximal to distal interjoint coordination, while the extension phase of lifting involved distal to proximal coordination.

To further expand upon their research on the interjoint coordination of lifting, Burgess-Limerick et al. (1995) studied 39 subjects (20 women and 19 men) lifting a load of increasing weight positioned on the floor. They were interested in determining the self-selected lifting technique adapted by these individuals, and the effect of increasing loads on interjoint coordination. The subjects performed 100 lifts in blocks of 5 with ascending weight in 2 kg increments (2.5 kg to 10.5 kg) for a total of 20 lifts per load. Ankle, knee, hip and lumbar spine kinematics were studied, as well as EMG activity of lower extremity muscles and errector spinae. The initial starting posture assumed by the subjects was described as "intermediate between the extremes of stoop and full squat" (p.405). Through the analysis of relative phase of the hip-knee and hip-lumbar spine, the authors determined that knee extension leads hip extension and hip extension leads lumbar extension, described as distal to proximal interjoint coordination. Furthermore, Burgess-Limerick et al. (1995) reported that the delay this distal to proximal interjoint coordination increased as load increased. The authors suggest that the delay in lumbar extension has the effect of maintaining the lengthened position of the errector spinae. Due to the length-tension relationship, the lengthening of the trunk extensors may result in increased trunk extensor strength during the initial part of the extension phase of lifting. Thus, the delay in distal to proximal interjoint coordination during lifting loads of increasing weight may serve as a "functionally relevant" (p.410) neuromuscular adaptation to task variations of increasing loads during the performance of lifting.

Scholz (1993) also investigated interjoint coordination during a lifting task where initial posture was specified and load variations were scaled to the subjects' maximum lifting capacity. Six male subjects lifted loads of 0, 15, 30, 45, 60 and 75% of their individual maximal lifting capacity. A total of 72 lift cycles were performed for each load in a random order. Relative phase calculations were used to examine interjoint coordination. The results indicated a change in timing between joints which supports previous findings of a delay in distal to proximal interjoint coordination as the load increased in weight, particularly from 45 to 75% of subject's maximum lifting capacity. This delay occurred only for the extension phase. Interjoint coordination during the flexion phase remained consistent across loads. Scholz (1993) concludes that although the initial staring posture remained the same for all loads lifted (squat), the technique used during the lift changed in response to variations in load. Thus, instructing a person in a specifiic lifting posture does not ensure that this posture will be utilized during the dynamic performance of the lift (p. 568).

This work was replicated by Scholz, Millford and McMillian (1995) using 15 male subjects who performed lifting as a part of their daily job duties. Scholz et al. (1995) found the same delay of interjoint coordination as the load to be lifted increased. As previously reported, this delay was significant only for the extension phase.

Research reviewed thus far regarding the kinematics of lifting has utilized subjects without previous history or current presence of low back pain. Boston, Rudy, Mercer and Kubinski (1993), however, compared lifting kinematics in subjects with and without chronic low back pain during a repetitive dynamic lifting task. Boston et al (1993) used the hip and knee angles to define the coordination of the lifting movement. The research design involved 10 controls and 10 patients performing repetitive lifting of a weight equal to 40% of each subject's average isometric lifting ability. The subjects performed the lifting task at a pace of 15 seconds per lift. The task was discontinued when a 20 minute time period was reached or the subjects could not continue at the determined pace. Motion analysis of the task was recorded using infra-red markers placed on the acromion, greater trochanter, apex of patella, and superior to lateral mallelous. These markers defined the knee angle (hip-knee-ankle markers) and the hip angle (shoulder-hip-knee markers). Body coordination was described during the extension phase by the midpoint, "the time at which half of the change (angular) has occurred" (p.139), and the risetime, "the time required for the angle to increase from 12 to 88% of the total change in angle" (p.139). Comparing the hip-knee midpoint difference and the hip-knee risetime difference provided an estimate of coordination with a zero difference indicating synchronous pattern of hip and knee extension, and a non-zero difference indicating uncoordinated movement. Boston et al (1993) reported that control subjects demonstrated coordinated movement, while the patient subjects demonstrated uncoordinated movement. The uncoordinated lifting pattern of the patients was characterized by knee movements preceding hip movements (positive midpoint difference) with the lag time between the hip and knee increasing throughout the movement (positive risetime difference). For the control subjects, knee movements preceded hip movements (positive midpoint difference), but the hip and knee completed the movement at the same time (negative risetime difference).

While previous research has investigated the kinematics of lifting, there are few studies that describe how treatment effects the kinematics of lifting (Boston, Rudy, Lieber, & Stacey, 1995; Lieber, Rudy, & Boston, 2000). Boston et al. (1995) conducted a study to measure the effects of a 3 1/2 week pain-rehabilitation program on repetitive lifting, including an investigation of body coordination as describe in the Boston el al (1993) study. Although the pain-rehabilitation program was not described, the authors note it was interdisciplinary and consisted of both group and individual treatment. Body coordination was determined through motion analysis of knee, hip and torso angles to determine midpoint and falltime, "the time required for the angles to decrease from 12 to 88% of the total decrease in the angles" (p.145). Comparing the hip-knee midpoint differences to the hip-knee falltime differences yielded an 'index of coordination', in which a negative value indicates synchronous, coordinated movement between the hips and knees, and a positive indicates asynchronous, uncoordinated movement between the hips and knees. Subjects consisted of 57 controls with no history of low back pain, and 68 patients with a 4.1 year average of chronic low back pain. Only the patients participated in the pain-rehabilitation program. Prior to initiating the treatment program, both patients and controls performed a repetitive dynamic lifting task as described in the study by Boston el al (1993). There was a significant difference between the coordination index between the controls (-0.31) and patients (-0.9). Following the conclusion of the 3 ½ week treatment program, the repetitive dynamic lifting task was repeated. There was a significant difference between the patient's pre-treatment index of coordination (-0.09) and the patient's post-treatment index of coordination (-0.31). There was no significant difference between the patient's post-treatment index of coordination and the control's index of coordination (-.031 and -.30, respectively). Additionally, the initial torso angle of the control subjects decreased by 4 degrees after treatment, indicating the use of a leg-style lift (squat technique). The controls, however, utilized more of a free-style technique, described to be between a torso lift and a leg lift.

Lieber et al (2000) continued this research with the inclusion of body mechanics training as part of an 8 week (average) work hardening program. Four subjects with lumbar pain of at least 3 months duration participated in the study. The repetitive lifting task and motion analysis was performed as described by Boston et al (1993) before and at the conclusion of the work-hardening program. Each subject's dynamic motion synchrony of the hip and knee joints (midpoint difference) and initial starting posture were evaluated as measures of body mechanics. Lieber et al (2000) report three of the four subject's to have a significant difference in hip-knee midpoint difference and starting posture as assessed during the pre and post treatment lifting task. Two of the four subjects demonstrated changes in starting posture from pre-test to post-test, with the starting posture becoming more of a squat lift (an increasing negative value for the difference between the hip-knee starting angles). Additionally, after body mechanic instruction, the synchrony between the hip and knee was not significantly different from that of control subjects. The authors conclude that body mechanics instruction had a significant effect on the performance of a repetitive lifting task.

Summary

The effects of practice under conditions of contextual interference during the learning of motor skills have been a topic of research with conflicting findings. Contributing to these conflicting findings are the use of tasks involving the same or different generalized motor programs, non-functional laboratory tasks verses research involving real-life tasks, as well as the skill and experience level of the learner. In general, the contextual interference effect is found more often in research involving parameter variations of the same generalized motor program (Del Ray et al., 1989; Pollock& Lee, 1990; Sekiya et al., 1994; Sekiya et al., 1996; Shea et al., 1990) than research in which the tasks are variations of different generalized motor programs (Bortoli et al., 1992; Brady, 1997; Pollatou et al., 1997; Sekiya et al., 1994; Sekiya et al., 1996; Wegman, 1999).

While most research employing non-functional laboratory based tasks has provided support for the CI effect (Del Rey, 1989; Seikya et al., 1994; Seikya et al., 1996; Shea et al., 1990; Sherwood, 1996), there have been varying findings research involving real-life tasks. Bortoli et al. (1992), Hall et al. (1994), Hanlon (1996), Landin & Hebert (1997), Pinto-Zipp (1996), Wegman (1999) and Wrisberg & Liu (1991) report support of the CI effect, where as, Brady (1997), Goodwin et al.

(1996), Hebert (1996), and Jarus & Goverover (1999) did not find support of the CI effect.

Del Ray et al. (1989), Hall et al. (1994), Shea et al. (1990) and Wegman (1999) found support for the contextual effect in subjects that were considered skilled, experienced or trained. In contrast, Hebert et al. (1996) found no benefit of high contextual interference for skilled subjects. Landin & Hebert (1997) report moderate contextual interference to be beneficial for experienced subjects For subjects who are unskilled or for whom the tasks are considered novel, some research has found high contextual interference to be beneficial (Pollock & Lee, 1997; Sekiya et al., 1994; Sekiya et al., 1996; Wrisberg & Liu, 1991), while other research has reported either no benefit of high contextual interference on the learning of a motor skill (Brady, 1997; Jarus & Goverover, 1999) or partial support of high contextual interference (Bortoli et al., 1992; Goodwin & Meeuwsen, 1996; Wegman, 1999). In studies using children as subjects, the CI effect was not found by Jarus & Goverover (1999) or by Pinto-Zipp (1996). Pollock & Lee (1997) and Wegman (1999) did report the benefit of high contextual interference for 7 year-olds and fourth grade girls, respectively.

While most research employing non-functional laboratory tasks have provided support for the CI effect (Del Rey, 1989; Seikya et al., 1994; Seikya et al., 1996; Shea et al., 1990; Sherwood, 1996), there have been varying findings for real-life or applied research. Bortoli et al. (1992), Hall et al. (1994), Hanlon (1996), Landin & Hebert (1997), Pinto-Zipp (1996), Wegman (1999) and Wrisberg & Liu (1991) report support of the CI effect, where as, Brady (1997), Goodwin et al. (1996), Hebert (1996), and Jarus & Goverover (1999) did not find support of the CI effect.

Practice is commonly employed in physical therapy treatment sessions to assist the patient in the learning of a motor skill. Only one research study has investigated how the incorporation of contextual interference during physical therapy treatment sessions affects motor skill learning (Hanlon, 1996). A motor skill commonly practiced in orthopedic and industrial rehabilitation is lifting. The kinematics of lifting have been described to involve distal to proximal interjoint coordination (Burgess-Limerick et al., 1993; Scholz, 1993). Further research has shown that synchronous distal to proximal interjoint coordination is disrupted as the weight to be lifted is increased (Burgess-Limerick et al., 1995; Scholz et al., 1995). The findings of Boston et al. (2000) provide evidence that the kinematics of lifting a constant load can be altered when subjects with low back pain receive practice involving body mechanics instruction.

From the research cited, there are varying findings regarding the effects of contextual interference on the learning of a motor skill, with only one study investigating the use of contextual interference during physical therapy treatment. Physical therapy treatment often involves the practice of a motor skill with the goal that the patient will be able to demonstrate learning through retention of the skill from session to session and through skill transfer to similar motor tasks. Thus, an understanding of how the use of contextual interference during a physical therapy treatment session may affect the learning of a motor skill is needed.

Chapter III

METHODOLOGY

Subjects

10 subjects, 5 males and 5 females, between the ages of 20-40, were recruited from Seton Hall University, and the communities of South Orange and Livingston, NJ as a sample of convenience (Appendix A). The subjects had no history of low back pain and no experience with industrial lifting. A musculoskeletal screening examination was administered by the investigator, a licensed physical therapist, to assess for postural asymmetries and range of motion limitations in the lumbar spine, hips, knees, and ankles. After passing the musculoskeletal screening, the subjects signed an informed consent (Appendix B) prior to their inclusion in the research study. Subjects were randomly assigned to one of two groups: 1) blocked practice; or 2) random practice.

Subject Preparation Procedures

Infra-red markers, 2.5 cm in diameter, were attached to major landmarks of the left extremities and to the trunk of each subject. Markers were attached with adhesive Velcro to the lateral mallelous, lateral femoral condyle, greater trochanter, immediately lateral and inferior to the acromion process, the sacrum, L3/4 interveterbal space, and T12 spinous process. These markers identified two-dimensional coordinates that were used to define five body segments: shank, thigh, trunk, lumbosacral, and lumbothoracic.

Procedures

Maximum lifting capacity

Prior to initiating practice, each subject's maximum dynamic lifting capacity (MDLC) was determined. Subjects performed five maximal effort isometric lifting trials against a dynamometer from a squat position in which the knees and hips are flexed with the back held relatively straight. The minimum and maximum values were eliminated, and the average peak force (F_{ave}) was calculated from the remaining 3 trials. Thirty percent of F_{ave} was considered the MDLC (Blackmore, Beaulieu, Baxter-Petralia, & Bruening, 1988). This value was used to determine loads that are 15%, 30%, 45%, 60% and 75% MDLC for the dynamic lifting tasks.

Materials

During the testing and practice conditions, each subject lifted an empty plastic crate that was 30.48 cm high, 30.48 cm deep, and 30.48 cm wide, and weighed 4 pounds. Handles were located on both sides of the box at a height of 21 cm from the floor that the subject used to grasp the crate. Weight plates were placed inside of the crate to increase the lifting load to a value equal to 15%, 30%, 45%, 60%, or 75% of MDLC .

Lifting task

From upright stance, the subject squatted to the floor to lift the crate from its resting position on the floor to a waist height position. The task was divided into two phases: 1) flexion: movement of the subject from upright standing to the floor using a squatting technique and 2) extension: movement of the subject from a squatting position to upright standing while holding the crate. One complete lifting cycle consisted of a flexion phase followed by an extension phase.

To begin the lift the subject stood at a self-selected distance from the crate with his/her feet at a self-selected distance apart. This self-selected distance represented a comfortable placement of the feet relative to the crate. The investigator placed tape on the floor, parallel and perpendicular to the subject's fifth metatarsals and at the corners of the crate. The tape allowed for repositioning of the subject's feet and the crate between testing trials.

For the lifting task, the subject stood in the initial starting position, squatted to the floor, grasped the handles of the box, and lifted the crate to waist height. The subject remained in upright standing, holding the crate, until the investigator cued the subject to return the crate to its resting position on the floor. Prior to each block of three lifts, the investigator will instructed the subject to:

> "Squat to the floor at the command 'go', reach for and grasp the handles of the crate, and lift the crate as you stand upright. Remain in an upright position until you receive the command "stop". At the command "stop", squat to the floor, place the crate on the floor, and release the crate. Return to an upright

> standing position after you release the crate. Perform this lifting movement at a comfortable speed. When squatting, bend your knees and keep your back vertically straight as possible."

Before the lifting acquisition, the investigator issued the above verbal instructions and demonstrated the lifting task to the subject. The subject performed 5 pre-practice trials of the lifting task with the empty crate to become familiar with the lifting procedures. During the 5 pre-practice trials, the investigator provided feedback to the subjects regarding their ability to follow the verbal instructions.

Data acquisition

Data was sampled at 120 Hz for 6 seconds, using the Pro Reflex Qualysis, Inc. MCU 1000 optoelectric three-dimensional motion analysis system. Three cameras recorded the position of infra-red markers, 2.5 cm in diameter, attached to major landmarks of the left extremities and to the trunk. These markers identified three-dimensional coordinates to define the shank, thigh, and trunk segments. Segment angles and joint angles (knee, hip and lumbar spine) were calculated from the transformed coordinates of each reflective marker. The knee angle was calculated from the shank and thigh segments. The hip angle was calculated from the thigh and trunk segments. Due to procedural complications with the sacral, lumbar and thoracic markers, lumbosacral angle was not analyzed.

Independent variables

The investigation involved three independent variables: practice condition, load lifted, and time. There were two levels of the independent variable practice condition: 1) blocked practice (low contextual interference); and 2) random practice (high contextual interference). In the blocked practice condition, subjects performed all trials of lifting a load of one weight before changing to another weight. In the random practice condition, subjects performed the lifting task in blocks of 3 lifting cycles in which the weight was varied for each cycle. Acquisition and retention test 1 occurred on the same day, where as, retention test 2 and the transfer test occurred 7 days following acquisition and retention test 1. There was a 15 minute rest period between acquisition and retention test 1. The second independent variable, load lifted, referred to the loads the subject lifted during acquisition and both retention tests (30%, 45% and 60% of MLC) and during transfer (15% and 75% MDLC). During retention, a third independent variable was tested, time between the first retention test on Day 1 and the second retention test on Day 7.

Dependent variables

Starting posture, lift duration, angular excursion, hip-knee midpoint difference, and index of coordination were the dependent variables that were studied. Starting posture was defined as the difference between the hip and knee angles at the onset extension phase of the lift. Lift duration was the time in seconds for the lifting task to be completed. Angular excursion was defined as the range of motion the knee and hip completed during the extension phase of the lifting task and was measured in degrees of flexion from upright extension (upright extension = 0°). The time required for the hip and knee to complete one half of their extension excursion represented the hip and knee temporal midpoints. The hip and knee midpoints were normalized by the total lift duration. Hip-knee midpoint difference was defined as the difference in the temporal midpoints of the hip and knee. Index of coordination was the correlation between the hip-knee midpoint difference and the hip-knee risetime difference. An index of coordination was calculated for each block of three trails.

Qualitative analysis was completed by visual inspection of scatterplots of the hip-knee midpoint differences against the hip-knee risetime differences. A scatterplot was completed for acquisition, retention test 1 (immediate retention, Day1), retention test 2 (delayed retention, Day 7) and transfer.

Experimental design

The experimental design involved acquisition practice, retention test 1, retention test 2, and a transfer test for both experimental groups. The day of the acquisition and retention test 1was considered day 1. At the conclusion of acquisition practice, the subjects in both experimental groups rested 15 minutes, after which time retention test 1 was given. Retention test 2 and the transfer test were conducted 7 days following acquisition and retention test 1 for all subjects. Subjects were given activity instructions to follow during the time interval between Day 1 and Day 7 (Appendix C). During acquisition and both retention tests, each subject performed the lifting task using loads of 30%, 45%, and 60% of MLC presented according to the experimental groups practice design. At the conclusion of the retention test, a transfer test was conducted in which each subject lifted two additional loads, 15% and 75% MLC. The experimental design is outlined in Appendix D.

Acquisition Phase. The intervention involved acquisition practice of the lifting task by the subjects assigned to the two experimental groups. The first nine trials of acquisition were recorded for motion analysis. During the first nine acquisition trials, the subjects in the blocked practice group performed three sets of three consecutive lifting cycles with each of the three testing loads. Subjects in the random practice group performed three lifting cycles of each load presented in a random order in sets of three with no one load being lifted more than 2 consecutive trials. At the conclusion of the first nine trials, acquisition continued unrecorded. Subjects in the blocked practice group performed nine consecutive trials of each load presented in blocks of three trials, for a total of 27 additional acquisition trials. For subjects in the random practice group, each of the three loads was presented in random order in blocks of three trials for a total of 27 additional acquisitions trials. During each block of three lifting cycles, no one load was lifted more than two consecutive times. There was a total of 36 acquisition trials for subjects in each experimental group. All subjects rested 1 minute between trials, and 2 minutes between blocks.

Retention Phase. There were nine retention trials, three trials for each load, in both retention test 1 and retention test 2. The trials were presented in blocked order in sets of three for subjects in the blocked practice group. For subjects in the random practice group, the nine trials were presented in random order in sets of three, with no one weight lifted more than two consecutive times. All subjects rested 1 minute between each set of 3 trials.

Transfer Phase. The transfer test consisted of each subject performing three lifting trials with a load that is 15 % MLC and 3 trials with a load that is 75% MLC. The loads were presented in blocked order for subjects in the blocked practice group, and in random order for subjects in the random practice group. Each subject rested 1 minute between each set of 3 trails.

Statistical Analysis

To determine the effect of practice under conditions of contextual interference on kinematic parameters of lifting, the results from this investigation were analyzed by separate repeated measures analysis of variance for acquisition, retention test 1 and retention test 2, and transfer. For acquisition, a two-way repeated measures analysis of variance (practice condition (2) *x* load lifted (3)) with repeated measures on the factor of load was performed. Retention test 1 and retention test 2 were analyzed using a three-way repeated measures analysis of variance (practice condition (2) x time (2) x load (3)) with repeated measures on the factors of time and load. Transfer tests were analyzed using two-way analysis of variance (practice condition (2) by load (2)) with repeated measures on the factor of load. The .05 level of significance was used for all statistical evaluations. Scheffe post hoc test of multiple comparisons was used for post hoc analysis for significant main effects.

Chapter IV

RESULTS

The purpose of this study was to examine the effects of practice organization involving conditions of high and low contextual interference on the coordination of the hip and knee movement during lifting loads of varying weight. The dependent variables describing coordination during lifting were starting posture, hip-knee midpoint difference and hip-knee index of coordination. Dependent variables describing time and displacement parameters during the lifting task were lift duration, and angular excursion of the hip and knee. This chapter is divided into the following sections: descriptive statistics, acquisition results, retention results, transfer results and discussion of findings.

Descriptive Statistics

The physical characteristics of the subjects are presented in Table 1. Mean values for age ($F(1,8) = .559$, $p = .476$), height ($F(1,8) = .488$, $p = .505$), and weight ($F(1,8) = 1.144$, $p = .316$) were not significant between practice conditions. Mean values for lifting capacity assessment and practice loads are presented in Table 2. There was no significant difference between conditions for MILC ($F(1,8) = 1.077$, $p = .330$), MDLC ($F(1.8) = 1.106$, $p = .343$), or load weights for 15% MDLC ($F(1,8) = 1.149$, $p = .315$), 30% MDLC ($F(1.8) = .951$, $p = .358$), 45% MDLC ($F(1,8) = 1.049$,

p = .336), 60% MDLC ($F(1,8) = 1.114$, p = .322), and 75% MDLC ($F(1,8) = 1.123$, p =.320).

Table 1

Descriptive Characteristics of Subjects

Practice Condition	Age (yr)	Height (inches)	Weight (lbs)
Blocked			
Mean	26.4	69	162.6
SD	3.97	4.18	45.69
Random			
Mean	28.8	67.2	138.2
SD	5.97	3.96	22.66

Table 2

Mean Maximum Isometric Lifting Capacity, Maximum Dynamic Lifting Capacity, Practice Load Weights

Practice Condition	MILC	MDLC	% MDLC 15%	30%	45%	60%	75%
Blocked							
Mean	212.6	63.8	9.6	19.1	28.7	38.3	47.8
SD	74.9	22.5	3.3	6.8	10.1	13.4	16.6
Random							
Mean	172.2	51.7	7.7	15.5	23.2	31.0	38.7
SD	44.4	13.4	1.8	3.8	6.0	8.1	10.0

Analysis of Variance Results for Dependent Variables

Means and standard deviations for each dependent variable during acquisition, retention and transfer experimental phases are contained in Appendix E. Presented in Appendix F are the ANOVA summary tables for each dependent variable. Tests of homogeneity of variances across loads for each testing phase were made using Levines's technique. The degree of heterogeneity was not significant for any dependent variable ($p > .05$).

Acquisition Results

A 2 (practice condition) *x* 3 (load) ANOVA with repeated measures on the last factor was carried out for each dependent variable. During acquisition, there were no significant main effects of practice condition and load for all dependent variables. The interaction between practice condition and load was significant for lift duration ($F(2,16) = 3.792$, $p < .05$), with an decrease in lift duration from 30% MDLC load (mean = 1.446 sec) to 60% MDLC load (mean = 1.286 sec) for the blocked practice condition. The main effect of load for hip excursion approached significance ($p = .052$), with overall mean hip excursion 98.397 degrees (30% MDLC), 98.484 degrees (45% MDLC), and 95.995 degrees (75% MDLC).

Retention Results

A 2 (practice condition) *x* 2 (time) *x* 3(load) ANOVA with repeated measures on the factors of time and load was carried out for each dependent variable. The main effect of practice condition was not significant for any dependent variable. The main effect of load was significant for lift duration and knee angular excursion. For all subjects, lift duration increased significantly ($F(2,16) = 10.764$, $p < .01$) as the load increased from 30% MDLC (mean lift duration = 1.177) to 45% MDLC (mean lift duration = 1.234) and from 30% MDLC to 60% MDLC (mean lift duration = 1.297).

The interaction between practice condition and load was significant ($F(2,16) = 6.319$, $p <.01$). For the random practice condition, the lift duration increased as the load increased, with significant differences in the lift duration between the 30% MDLC load (mean = 1.180 sec) load and the 60% MDLC load (mean = 1.387 sec), and between the 45% MDLC load (mean = 1.216 sec) and the 60% MDLC load. For the blocked practice condition, the lift duration increased significantly between the 30% MDLC load (mean = 1.172 sec) and the 45% MDLC load (mean = 1.252 sec).

Additionally, there was a significant main effect of load for knee angular excursion ($F(2,16) = 4.181$, $p = .035$). The overall mean knee excursion was significantly greater at the 60% MDLC load (mean = 90.105) as compared to the 30% MDLC load (mean = 86.884). All other results during the retention phases were not significant.

Transfer Results

A 2 (practice condition) *x* 2 (load) ANOVA with repeated measures on the last factor was carried out for all dependent variables. While the main effect of practice condition was not significant for all dependent variables, the main effect of load was significant for lift duration, midpoint difference, index of coordination, and hip and knee angular excursion.

The results of the ANOVA for lift duration yielded a significant main effect of load ($F(1,8) = 26.885$, $p = .001$) and a significant practice condition x load interaction ($F(1,8) = 6.128$, $p = .038$). The overall mean lift duration increased as the load increased from 15% MDLC (mean = 1.110 sec) to 75% MDLC (mean = 1.420 sec). While there was no evidence of a difference in overall lift duration between practice conditions ($F(1,8) = 2.594$, $p > .05$), random practice resulted in a greater lift duration than blocked practice at the 15% MDLC load (mean = 1.600 sec and 1.240 sec, respectively), and the lift duration increased when lifting the 75% MDLC load for both practice groups.

Midpoint difference between the hip and knee was significantly less ($F(1,8) = 6.602$, $p = .033$) at the 15% MDLC load than at the 75% MDLC load. The overall mean midpoint difference for the 15% MDLC load was 0.0244 and 0.0885 for the 75% MDLC load, indicating decreased synchronization between the hip and knee during the heavier loads for both practice conditions (Figure 1).

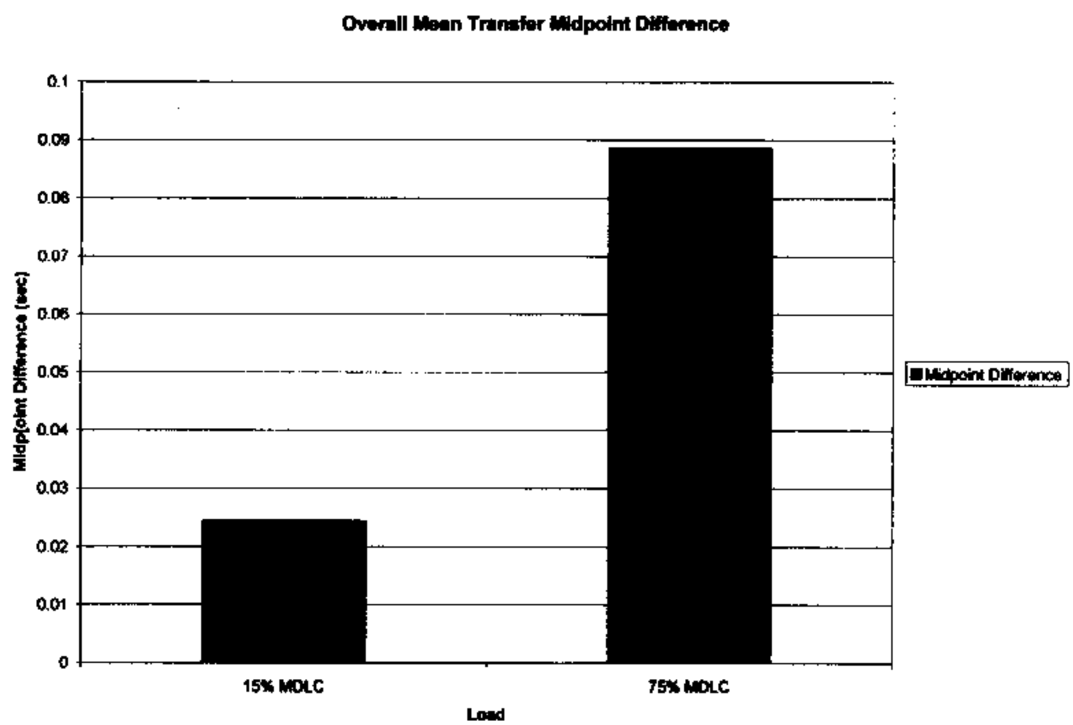


Figure 1. Overall mean midpoint difference (hip-knee) during transfer tests with loads 15% MDLC and 75% MDLC (p =.033).

Similarly, there was a significant difference in the index of coordination between the 15% MDLC load and the 75% MDLC load ($F(1,8) = 11.161$, $p = .010$). The overall mean index of coordination for the 15% MDLC load was 0.718 and -0.250 for the 75% MDLC load (Figure 2).

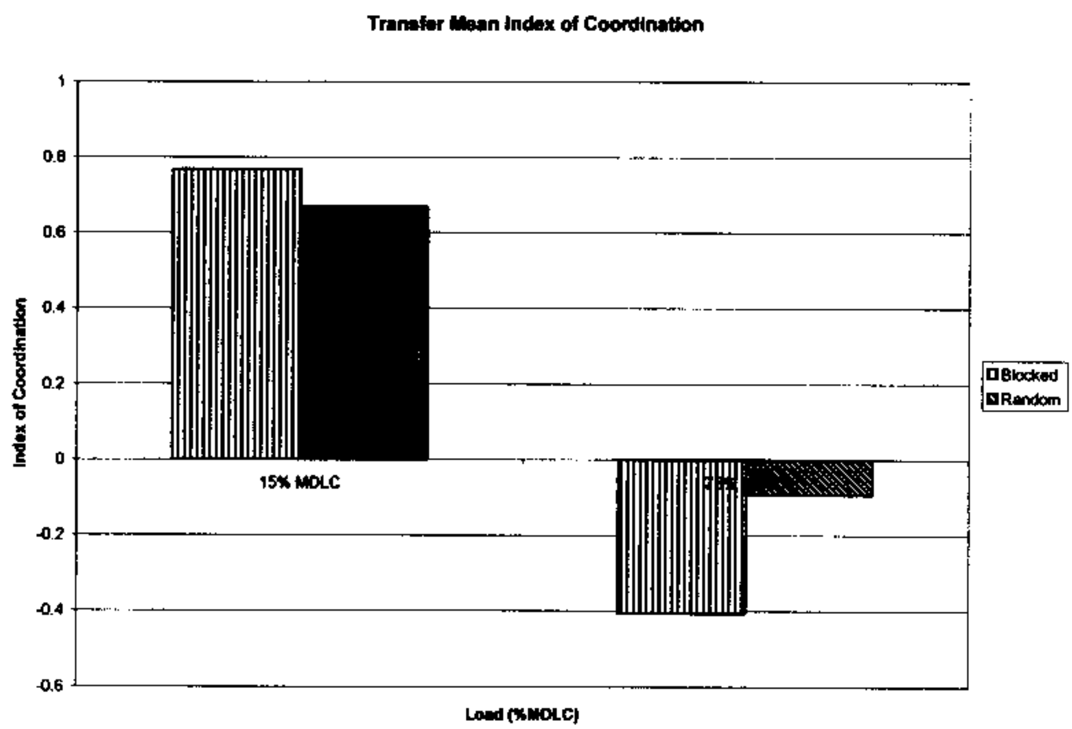


Figure 2. Mean index of coordination for blocked and random practice conditions when lifting loads 15% MDLC and 75% MDLC.

Both knee and hip angular excursions were significantly greater at the 75% MDLC load. The mean overall hip excursion was 100.529 degrees at the 75% MDLC load as compared to 93.154 degrees at 15% MDLC load ($F(1,8) = 13.031$, $p =$

.007). Similarly, knee excursion was significantly greater at 75% MDLC (mean = 90.749) than at 15% MDLC load (mean = 85.521) ($F(1,8) = 6.016$, $p = .040$). The interaction of practice condition and load was significant for knee excursion ($F(1,8) = 6.310$, $p = .036$), with subjects in the random practice group having greater knee excursion at the 75% MDLC load (random mean 75% MDLC = 97.342, blocked mean 75% MDLC = 84.156).

Qualitative Description of Lifting Performance

Scatterplots of hip-knee midpoint differences against hip-knee risetime differences provided qualitative descriptions of lifting performance during acquisition, retention and transfer. The four quadrants of the scatterplots correspond to different coordination patterns of the hip and knee as shown in Figure3. Midpoint-risetime scatterplots for acquisition, retention and transfer are presented in figures 4-6. The number of lifts in each quadrant by experimental group for all testing phases is presented in Table 3.

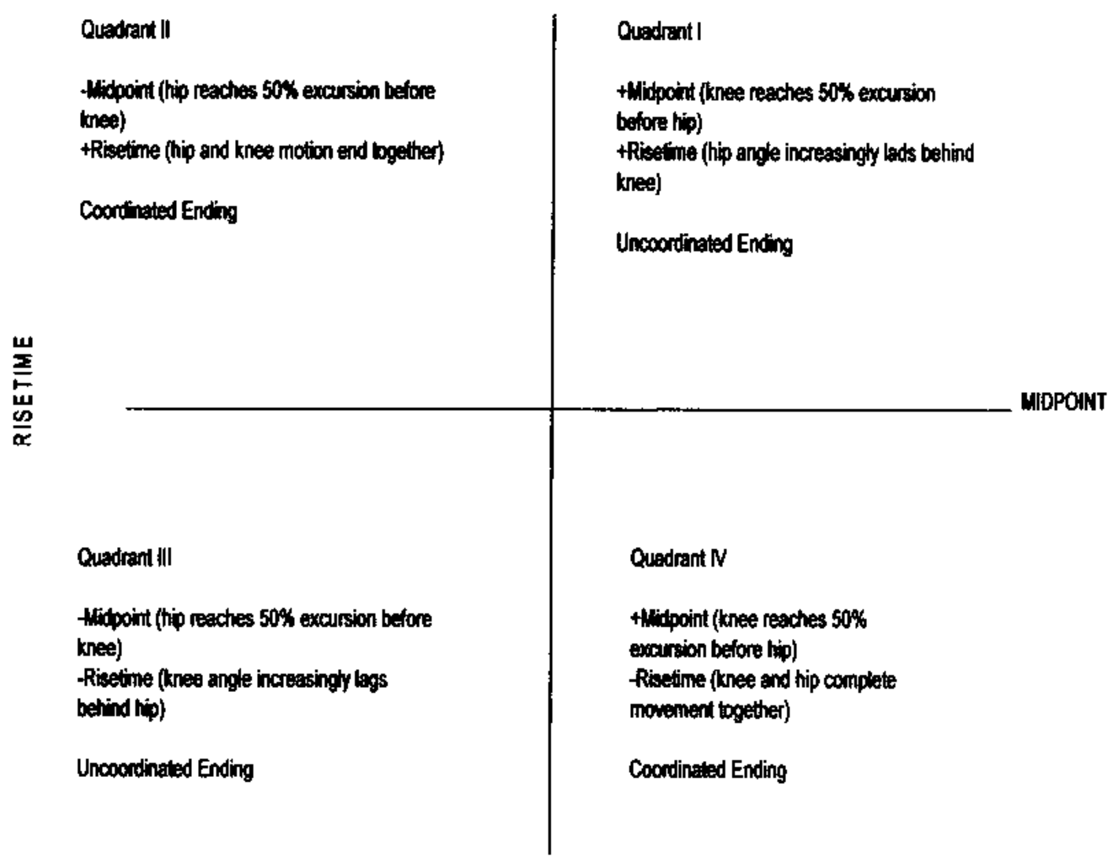


Figure 3. Summary of quadrant in scattergram plot of midpoint difference against risetime difference.

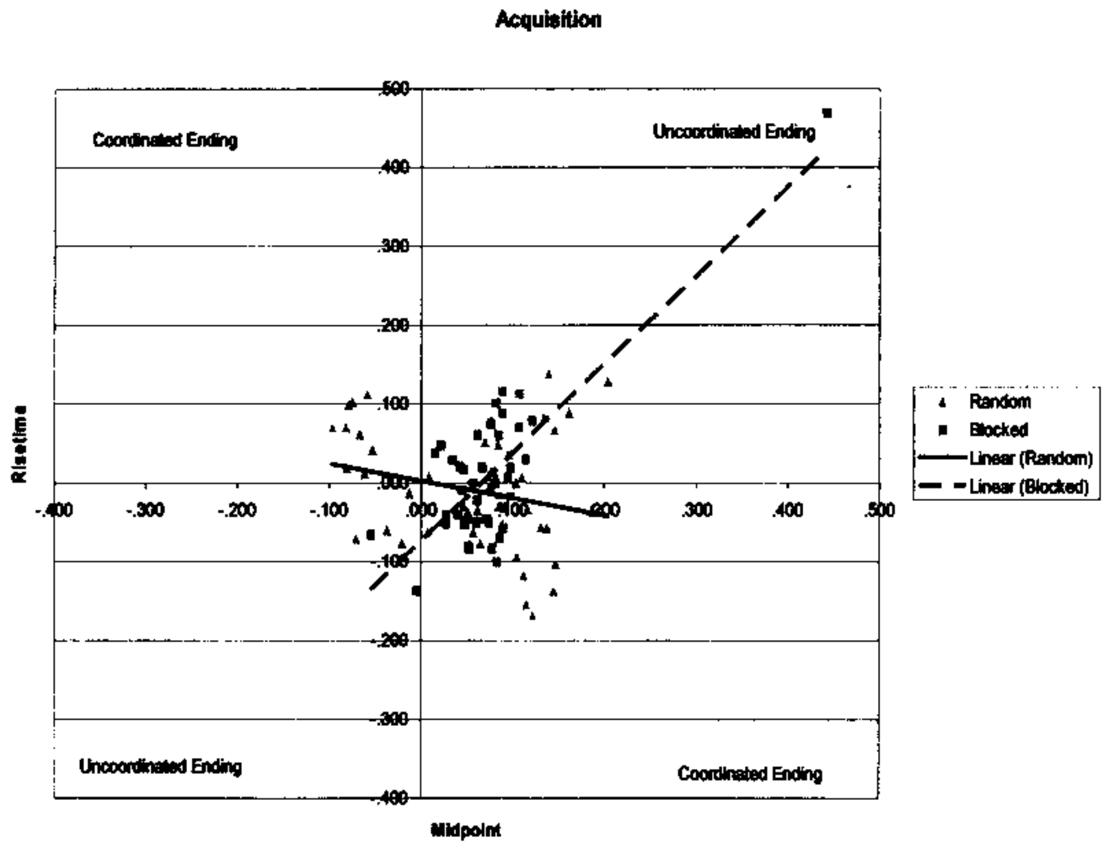


Figure 4. Acquisition midpoint against risetime across all loads for blocked and random practice conditions.

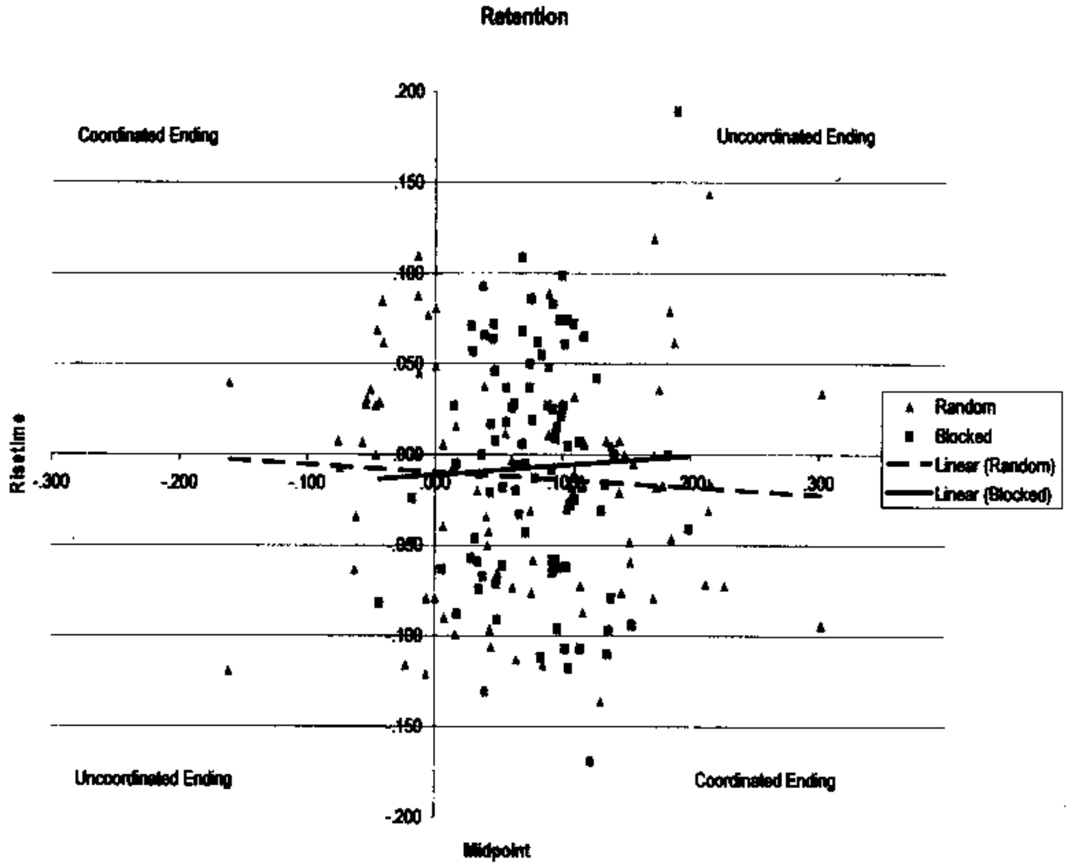
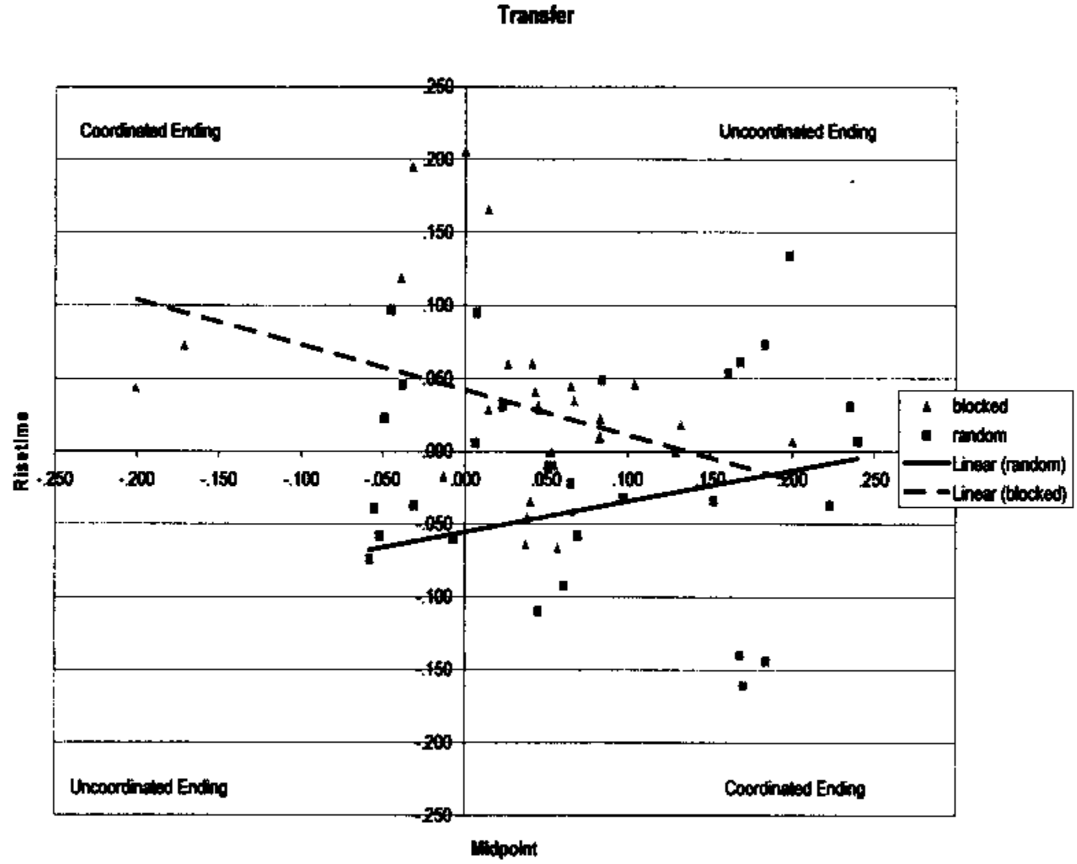


Figure 5. Retention Day 1 and Retention Day 7 midpoint against risetime across all loads for blocked and random practice conditions.



<u>Figure 6.</u> Transfer midpoint against risetime across all loads for blocked and random practice conditions.

Table 3

Number of Lifts in Each Quadrant by Condition and Testing Phase

	Quadrant				
	I	II	III	IV	TOTAL
Random					
Acquisition	11	9	4	21	45
Retention 1	10	9	4	21	45
Retention 2	14	8	3	20	45
Transfer	10	3	6	11	30
TOTAL	46	31	15	73	165
Blocked					
Acquisition	25	1	1	18	45
Retention 1	20	0	2	23	45
Retention 2	24	0	1	20	45
Transfer	18	4	1	7	30
TOTAL	87	5	5	68	165

During acquisition there were a total of 45 lifts analyzed per practice condition (3 trials per each load per subject). During each retention test, 90 trials were analyzed per practice condition and during transfer, 30 trials were analyzed per practice condition. The percent of lifts resulting in coordinated ending between the hip and knee are presented in Table 4 and Figure 7.

Table 4

Percent of Lifts with Coordinated Ending Between the Hip and Knee

	Acquisition	Retention 1	Retention 2	Transfer
Blocked	42.2	51.1	44.4	36.7
Random	66.7	68.9	62.2	46.7

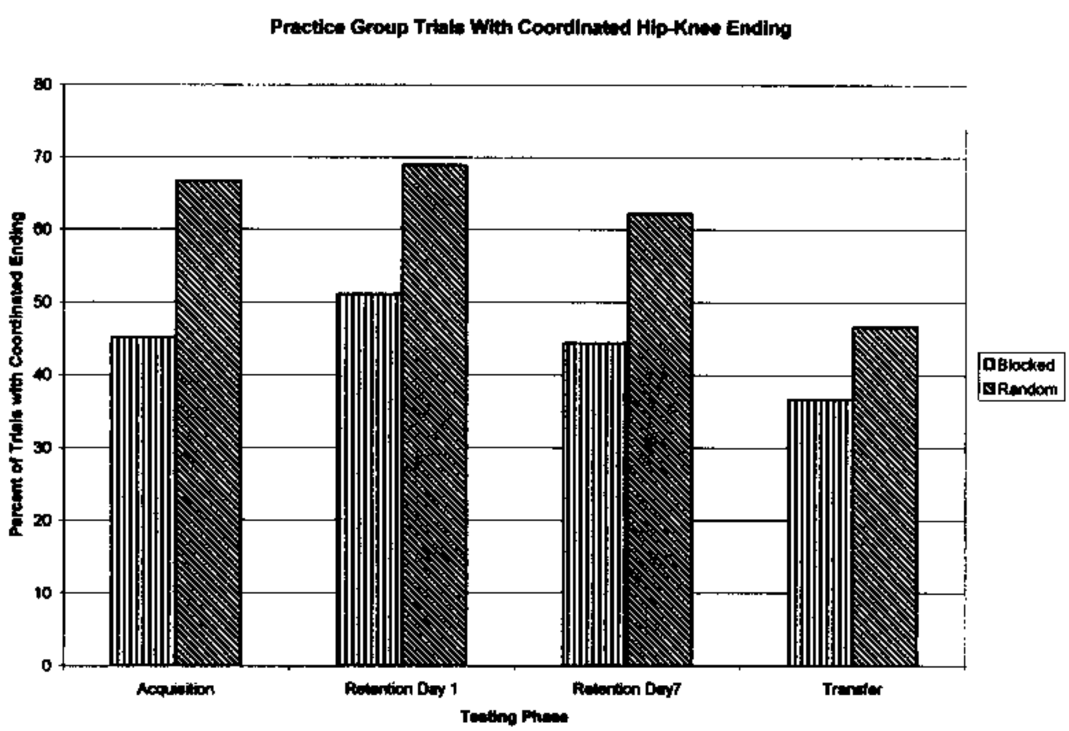


Figure 7. Percent of trails for each practice condition with coordinated hip-knee endings during each testing phase

Quadrants II and IV represent lifts in which there was coordinated movement ending between the hip and knee. For both practice groups, a greater percentage of the lifts with a coordinated ending utilized a strategy described by quadrant IV in which the knee attained 50% extension excursion before the hip, but knee and hip motion ended together. Additionally, both practice groups had a greater percentage of the lifts with an uncoordinated ending occurring in quadrant I. This strategy is one in which knee motion attained 50% extension excursion before the hip and the knee completed its extension excursion before the hip.

Chapter V

DISCUSSION

The dependent variables lift duration and hip, knee angular excursions are discussed in the first section and the dependent variables starting posture, midpoint difference and index of coordination are discussed in the second section. Practice organization is discussed in the third section.

Lift Duration and Angular Excursion

As expected, there was no difference between practice groups for lift duration and angular excursion. At the onset of practice, all subjects displayed similar time and displacement parameters while lifting. Lift duration for the random practice group was consistent across loads. The blocked practice group utilized a longer lift duration when lifting the 30% MDLC load as compared to the 45% MDLC. There was a trend (p=.052) for hip excursion to be greater at the higher loads for both practice groups. Thus, subjects in the blocked practice group may have increased lift duration at the 30% MDLC load to accommodate the greater range of hip extension excursion.

During retention and transfer, the effect of load on lift duration occurred for both practice groups. In contrast to acquisition, the overall lift duration increased during retention as the load increased from 30% MDLC to 45% MDLC and from 30% MDLC to 60% MDLC. Overall knee excursion also increased at the 60%

MDLC load as compared to the 30% MDLC load. As in acquisition, the increase in angular excursion occurred with an increased lift duration. Similar results were found during transfer where there was a longer lift duration and greater knee and hip excursion at the 75% MDLC load. These increases in lift duration and knee excursion when lifting the 75% MDLC load were greater for the random practice condition.

The finding of increase in lift duration as load is increased is in agreement with results of previous research. Burgess-Limerick (1995) reported lift duration to increase from 1.15 seconds to 1.29 seconds when subjects lifted loads ranging from 2.5 kg to 10.5 kg (5.5 lb to 23.1 lb). Scholz (1992) found lift times to increase from 1.029 seconds at 15% maximum lifting capacity to 1.113 seconds at 75% maximum lifting capacity. In a study by Holmes (1992), lift times increased from 1.5 seconds when lifting unloaded to 2.5 seconds when lifting 30 lbs. Likewise, Gargnon and Smyth (1992) found movement time to increase from 1.1 seconds to 1.3 seconds as load increased from 6.4 kg (14.08 lb) to 11.6 kg (25.52 lb).

The changes in lift times that occurred as loads increased may serve to minimize peak moments and forces in the spine. Peak moments in the lumbar spine at L5/S1 have been found to increase when loads are increased and when the speed of lifting increases (Buseck, M., Schipplein, O.D., Andersson, G.B.J., & Andriacchi, T.P., 1988; Kjellberg et al., 1998). Additionally, compression forces were reported to be higher when subjects' movement speed increased during the lifting of both light (6.4 kg) and a heavy (11.6 kg) loads (Gargnon and Smyth, 1992). In the present study, subjects slowed their movement time as loads increased during retention and transfer, while lift duration remained consistent across loads in acquisition. This suggests a benefit of practice independent of practice condition.

Starting Posture, Midpoint Difference and Index of Coordination

Starting posture at lift onset was defined as the difference in the initial angles of the hip and knee, with a positive difference >60° indicating a back lift, a 0-55° difference indicating a leg lift, and a negative difference indicating a squat lift (Lieber et al., 2000). Throughout all testing phases, the hip-knee initial angle difference was between 0- 55°, indicating that the subject's starting posture was that of a leg lift. This posture did not differ between practice groups or across loads. Thus, the coordination of flexion between the hip and knee at lift onset remained unchanged despite different practice conditions and when lifting varying loads.

The hip-knee midpoint difference and index of coordination also remained unchanged for both practice groups across all loads during acquisition and retention. The midpoint difference was positive, indicating that that knee attained 50% of its extension excursion at an earlier time in the lift cycle. This supports previous research describing a distal to proximal coordination between the hip and knee during the extension phase of lifting (Burgess-Limerick et al., 1993). During transfer, however, increasing the load from 15% MDLC to 75% MDLC resulted in a greater hip-knee midpoint difference and a more negative index of coordination for all subjects. The increase in hip-knee midpoint difference indicated that there was a delay in the distal to proximal coordination between the knee and hip. The negative index of coordination, however, reflects that the hip and knee motion was coordinated to end the lifting movement together, thus preserving the synchronization between the hip and knee.

Previous researchers have reported delays in the distal to proximal coordination between the knee and hip during the extension phase of lifting as loads are increased (Burgess-Limerick, Scholz). In these studies, the performance of lifting was assessed under variations in loads absent of practice. The present study, however, assessed the effect of two practice schedules on the lifting performance as loads were varied. While other research reported the delay in hip-knee coordination to occur with loads of 45%, 60% and 75% maximum lifting capacity (Scholz, 1992, 1995), increases in hip-knee midpoint difference in the present study occurred only during transfer when subjects were lifting the 75% MDLC load. This load was not practiced during acquisition or retention, but was chosen as a load outside of the practice load range to assess motor skill learning. Despite increases in hip-knee midpoint difference when lifting the 75% MDLC load, all subjects were able to adapt a movement strategy in which hip and knee motion was coordinated to end the lift together.

Contextual Interference

The benefit of a random practice schedule on lifting performance was expected to be demonstrated during retention and transfer. It was predicted that, subjects practicing under conditions of high contextual interference would demonstrate more of a squat style starting posture than that of the subjects practicing under conditions of low contextual interference. The midpoint difference was hypothesized to be greater for subjects in the blocked practice group, while the index of coordination more negative for subjects in the random practice condition.

The failure to find practice group differences in the present study may be the result of limited practice provided during acquisition. Acquisition consisted of 36 practice trials provided in a single session lasting approximately 30 minutes. This practice design was selected to resemble a physical therapy session in which a functional task such as lifting is typically practiced. Additionally, one practice session was chosen to reflect the minimum weekly frequency of physical therapy sessions an individual may schedule. The number of practice trails was also selected to resemble the number of repetitions commonly used when performing a lifting task in a physical therapy session. This design differs from that used by other contextual interference research that has found random practice schedules to be beneficial in the learning of functionally oriented motor skills. In these studies, the number of practice trials per session was similar to that used in the present study, but more practice sessions were included. Nine practice sessions of 36 trials per session were provided in the learning of badminton serves where random practice was found to enhance retention and transfer (Goode and Magill, 1986). Likewise, Landin and Hebert (1997) utilized 5 sessions of 30 trails per session for practice of basketball set shot and found moderate contextual interference beneficial in retention.

Another factor possibly contributing to the lack of practice condition effect is the prior experience and skill of subjects in the present study. Although subjects did not participate in occupational lifting, they had prior experience with lifting as part of daily activities. Thus, it was assumed that subjects had an existing motor plan for lifting and were in the later stages of learning. Given these factors, it was expected that subjects would benefit from a random practice schedule and not need extended practice. Since lifting performance was consistent between groups during acquisition, retention and with the 15% MDLC transfer load, all subjects may have had a preexisting high level of skill with lifting that did not advance with one practice session of 36 trials. Similar findings were reported by Bortoli et al. (1992) and Hebert et al. (1996) who found no benefit of random practice over blocked practice for high skilled subjects. Alternatively, the consistent lifting style observed may indicate that subjects already had an optimal lifting strategy that was not challenged by the level of interference provided in the practice session. It was not until the load reached 75% MDLC that differences in midpoint and index of coordination emerged. Thus, for subjects with high skill level and prior experience, the amount of interference provided through a random schedule of load variations may not be sufficient to enhance retention and transfer. The use of different objects and/or lifting from different heights, or more challenging loads may have created a higher degree of interference, allowing the benefits of random practice to emerge.

Since previous research has found an increase in the delay in the distal to proximal coordination between the knee and hip when lifting increasing loads, it was predicted that the use of a random practice schedule would prevent this increased delay, thus improve lifting performance during retention and transfer. Thus, measures of lifting performance were made expecting to see a beneficial change for the random practice condition during retention and transfer. The investigator was expecting a change in movement strategy, instead, the subjects accomplished the task without changing movement strategy when lifting loads 15%-60% MDLC. In attempt to establish a change in the motor control of lifting, perhaps the importance of the resulting consistency in lifting performance across loads and time was missed.

Index of coordination was the primary measure of coordination between the hip and knee. In reviewing the procedures used to measure index of coordination a major limitation was noted. The calculation of index of coordination did not represent the qualitative description of hip-knee synchronization that is presented through scatterplots of midpoint difference against risetime difference. The index of coordination, calculated as described by Boston et al. (1993), is the correlation between midpoint difference and risetime difference. According to Boston et al. (1993), a positive index of coordination represents uncoordinated movement between the hip and knee, while a negative index of coordination represents coordinated movement between the hip and knee. In this study, an index of coordination was calculated for each subject using three trials at each load in acquisition, retention and transfer. For each practice condition, this resulted in five indexes of coordination per load per testing phase. The mean index of coordination was calculated in the repeated measures analysis of variance statistics. The resulting mean indexes of coordination for loads and practice conditions differ from the correlation of midpoint and risetime as calculated across all trials of a load per practice condition and represented in the scatterplots.

Quadrants II and IV describe movement patterns in which the temporal separation between the hip and knee decreased during the lift to produce a coordinated ending between these joints. Quadrants I and III describe movement patterns in which the temporal separation between the hip and knee increase during the lift to result in an uncoordinated ending between these joints. Frequency counts of the number of lifts represented in each quadrant of the scattergram describe the lifting pattern used by each group (Table 27, Table 28, Ch. 4). During acquisition, retention and transfer, the percent of lifts contained in quadrants II and IV for the blocked practice condition were 46.7%, 70% and 60% respectively. For the random practice condition, 73.7%, 70% and 40% of lifts were in quadrants II and IV during acquisition, retention and transfer, respectively. In contrast, the index of coordination for blocked practice condition was positive during acquisition and transfer, and negative during retention. The index of coordination for the random practice condition was positive for acquisition, retention and transfer. Thus, the calculation of index of coordination may not provide a precise enough measure of movement coordination between the hip and knee to detect group differences as a result of practice.

In summary, there was no benefit of random practice over blocked practice on the lifting performance of varying loads during retention and transfer. This supports prior findings from contextual interference studies utilizing functional tasks and skilled subjects (Bortoli et al, 1992, Hebert et al, 1996). However, the methodological concerns regarding the amount of practice, subject skill level, and the use of index of coordination to describe hip-knee coordination may have masked any contextual interference effects.

Chapter VI

SUMMARY AND CONCLUSIONS

Summary of Findings

It was hypothesized that subjects practicing under conditions of high contextual interference would demonstrate more optimal lifting performance during retention and transfer as compared to subjects practicing under conditions of low contextual interference. Optimal lifting performance would be defined through starting posture (initial hip angle - initial knee angle less for random practice condition), midpoint difference (greater for blocked practice condition) and index of coordination (more negative for random practice condition). There was no difference between random and blocked practice conditions for all dependent variables. However, changes in load weight did affect lift duration, hip excursion, knee excursion, midpoint difference, and index of coordination.

During acquisition, lift duration increased between the 30% MDLC load and the 45% MDLC load. Examination of the interaction between load and practice condition revealed that subjects in the blocked practice condition increased lift duration at the 30% MDLC load as compared to the 60% MDLC. During retention, overall load duration increased between the 30% MDLC load and the 45% MDLC load, and between the 30% MDLC load and the 60% MDLC load. Knee excursion also increased during retention at the 60% MDLC load as compared to the 30% MDLC load. When lifting the 75% MDLC transfer load, all subjects increased lift duration, hip excursion, and knee excursion. This was the only load that resulted in a change in synchronization between the hip and knee. For all subjects, the midpoint difference increased, indicating delay in distal to proximal coordination between the hip and knee at the time in the lift cycle in which the hip and knee each completed 50% of their extension excursion. Of importance, is the corresponding negative index of coordination which reflects that subjects were able to adjust their movement strategy, resulting in a coordinated movement ending between the hip and knee. Although both practice conditions increased lift duration at the 75% MDLC load, lift duration was longer for the random condition.

Based on subject's prior experience with lifting, it was assumed that the subjects were in the later stages of learning, would not need extended practice sessions, and would benefit more from random practice. However, because of the subject's high skill level with lifting that was apparent through measures of lifting performance during acquisition, the benefits of random practice did not emerge with the amount of practice and interference provided to these subjects. Additionally, the use of index of coordination to quantify hip-knee coordination may not have provided a precise enough measure of performance.

Conclusions

The purpose of this study was to examine the effect of practice organization involving conditions of high and low contextual interference on the coordination of the lower extremity, describe through starting posture, midpoint difference, and hip-knee index of coordination, as subjects lift loads of increasing weights. The results of this study indicate no difference between the use of a blocked practice schedule or the use of a random practice schedule on the performance of lifting during acquisition, retention and transfer for subjects with prior lifting experience. Upon review of the statistical findings, the following conclusions are drawn:

1. During acquisition across all loads, there was no significant difference in the starting posture, hip-knee midpoint difference and index of coordination between subjects practicing under conditions of high contextual interference and subjects practicing under conditions of low contextual interference. The research hypothesis is accepted.
2. During retention and transfer tests across all loads, there was no difference between practice conditions in the starting posture flexion angle of the hip and knee. The research hypothesis is rejected.
3. During retention tests and transfer tests, there was no difference between groups in the hip-knee midpoint difference. At the 75% MDLC load, the hip-knee midpoint difference was greater for subjects practicing under conditions of high contextual interference than subjects practicing under conditions of low contextual interference. The research hypothesis is rejected.
4. During retention and transfer tests, there was no difference between practice conditions in the index of coordination. For all subjects, when lifting the 75% transfer load, the index of coordination was decreased as compared to the index of coordination at the 15% MDLC load. The research hypothesis is rejected.

Clinical Implications

The practice of motor skills is commonly employed in physical therapy treatment sessions for the remediation of function and prevention of injury. While improvement in performance is noted during and after practice, learning is demonstrated through retention of the skill from session to session and through skill transfer to similar motor tasks. Methods to optimize learning and, thus, enhance clinical outcomes, are continually explored by the therapist. Based on prior research findings of the benefits provided by high contextual interference during practice on the retention and transfer of motor skills, a therapist may choose to organize practice sessions to include interference through the use of a random practice schedule. However, based on the results of this study, careful consideration of the learner and the task should be made before generalizing research findings to clinical practice.

It is often assumed by clinicians that fewer practice trials or sessions are needed if a patient has a high skill level or prior experience with the motor task. Additionally, a limited number of sessions are often imposed on therapists by third party payers. The results of the present study suggest that subjects with prior experience or high skill level may require extended practice before improvement is observed and retention of skilled performance is achieved.

Findings from the present study also suggest that a thorough assessment of the level of interference adequate to challenge acquisition performance is necessary before initiating practice. When working with patients who have prior experience with lifting and/or have an established a degree of proficiency with the task, varying loads may not create adequate interference to facilitate motor plan reconstruction necessary to advance skill performance. The use of difference objects, more challenging weights, or lifting to and from different heights may provide a more effective stimulus for learning. The amount of interference necessary to promote motor skill learning is unique to each individual. Additionally, the nature of the task must also be considered when determining the amount of interference to provide during practice. Once skill with lifting is acquired, the task often becomes repetitive in nature despite variations in loads. At this point in learning, interference using a dissimilar task that requires a different motor pattern, such as reaching overhead, may be more beneficial in skill learning. When practicing these dissimilar tasks using a random schedule, the patient is required to continually regenerate the motor program for lifting, and strengthen the retention and transfer of lifting performance.

Therapists should be cautioned when the goal of practice is to elicit a change in a motor program. Successful performance of a motor skill, requires the patient to develop a movement strategy to meet the demands of the task and the environment within the musculoskeletal constraints of the individual. Learning of the skill may be better assessed as the stability of the movement pattern over time when performed under the same task and environmental conditions.

In summary, the beneficial effects of practice organization are influenced by characteristics of both the individual and the task. The findings of this study and previous contextual interference research suggest that there is not a definitive method of practice organization most effective in promoting the learning of functional tasks.

Instead, theoretical knowledge gleamed from research findings provides a framework for practical experimentation in the clinic. The results of this study encourage therapists to explore different methods of practice organization through the continual adaptation of treatment sessions to meet abilities of the patient and the demands of the tasks. From this exploration, clinical outcomes will emerge that will establish the effectiveness of therapeutic interventions on the learning of motor skills.

Bibliography

American Physical Therapy Association. (1997). Guide to physical therapy practice (1st ed.). Alexandria, VA: Author.

Blackmore, S. M., Beaulieu, D., Baxter-Petralia, P., Bruening, L. (1988). A comparison study of three methods to determine exercise resistance and duration for the BTE work simulator. Journal of Hand Therapy, July-Sept, 165-171.

Bortoli, L., Robazza, C. V., & Carra, C. (1992). Effects of contextual interference on learning technical sports skills. Perceptual and Motor Skills, 75, 555-562.

Boston, J. R., Rudy, T. E., Mercer, S. R., & Kubinski, J. A. (1993). A measure of body movement coordination during repetitive dynamic lifting. IEEE transactions on Rehabilitation Engineering, 1(3), 137-144.

Boston, J. R., Rudy, T. W., Lieber, S. J., & Stacey, B. R. (1995). Measuring treatment effects on repetitive lifting. Journal of Spinal Disorders, 8(5), 342-351.

Brady, F. (1997). Contextual interference and teaching golf skills. Perceptual and Motor Skills, 84, 347-350.

Burgess-Limerick, R., Abernethy, B., & Neal, R. J. (1993). Relative phase quantifies interjoint coordination. Journal of Biomechanics, 26(1), 91-94.

Burgess-Limerick, R., Abernethy, B., Neal. R.J., & Kippers, V. (1995). Self-selected manual lifting technique: functional consequences of the interjoint coordination. Human Factors, 37(2), 395-311.

Burgess-Limerick, R., Shemmell, J., Barry, B.K., Carson, R. G., & Abernethy, B. (2001). Spontaneous transitions in the coordination of a whole body task. Human Movement Science, 20, 549-562

Buseck, M., Schipplein O. D., Andersson, G.B.J., & Andriacchi, T.P., (1988). Influence of dynamic factors and external loads on the moment at the lumbar spine in lifting. Spine, 13,(9), 918-921.

Del Rey, P. (1989). Training and contextual interference effects on memory and transfer. Research Quarterly for Exercise and Sport, 60(4), 342-347.

Gagnon, M., and Smyth, G. (1992). Biomechanical exploration on dynamic modes of lifting. Ergonomics, 35(3), 329-345.

Goodwin, J. E., & Meeuwsen, H. J. (1996). Investigation of the contextual interference effect in the manipulation of the motor parameter of over-all force. Perceptual and Motor Skills, 83, 735-743

Hall, K., Domingues, D. A., & Caavazos, R. (1994). Contextual interference effects with skilled baseball players. Perceptual and Motor Skills, 78, 835-841.

Hanlon, R. (1996). Motor learning following unilateral stroke. Archives of Physical Medicine and Rehabilitation, 77, 811-815.

Hebert, E. P., Landin, D., & Solmon, M. A. (1996). Practice schedule effects on the performance and learning of low- and high-skilled students: an applied study. Research Quarterly for Exercise and Sport, 67(1), 52-58.

Jaurs, T. (1994). Motor learning and occupational therapy: the organization of practice. The American Journal of Occupational Therapy, 48(9), 810-816.

Jarus, T. & Goverover, Y. (1999). Effects of contextual interference and age on acquisition, retention, and transfer of motor skill. Perceptual and Motor Skills, 88, 437-447.

Kjellberg, K., Lindbeck, L., & Hagberg, M. (1998). Method and performance: two elements of work technique. Ergonomics, 41(6), 798-816.

Landin, D. & Hebert, E. P. (1997). A comparison of three practice schedules along the contextual interference continuum. Research Quarterly for Exercise and Sport, 68(4), 357-361.

Lieber, S. J., Rudy, T. E., & Boston, R. (2000). Effects of body mechanics training on performance of repetitive lifting. The American Journal of Occupational Therapy, 54(2), 166-175.

Magill, R. A., & Hall, K. G. (1990). A review of contextual interference effect in motor skill acquisition. Human Movement Science, 9, 241-289.

Magill, R. A. (1998). Motor learning: Concepts and applications, Boston: McGraw-Hill.

Pollatou, E., Kioumourtzoglou, E., Agelousis, N., & Mavromatis, G. (1997). Contextual interference effects in learning novel motor skills. Perceptual and Motor Skills, 84, 487-496.

Pinto-Zipp, G. (1996). Practice schedule and motor learning: Children verses adults. (Doctoral dissertation. Columbia University, 1996).

Pollock, B., & Lee, T. D. (1997). Dissociated contextual interference effects in children and adults. Perceptual and Motor Skills, 84, 851-858.

Scholz, J. P. (1993). Low back injury and manual lifting: review and new perspective. Physical Therapy Practice, 1(3), 20-31.

Scholz, J. P., Millford, J. P., & McMillan, A. G. (1995). Neuromuscular coordination of squat lifting I: effect of load magnitude. Physical Therapy, 75(2), 119-132.

Seikya, H., Magill, R. A., Sidaway, B., & Anderson, D. I. (1994). The contextual interference effect for skill variations from the same and different generalized motor program. Research Quarterly for Exercise an Sport, 65(4), 330-338.

Seikya, H., Magill, R. A., & Anderson, D. I. (1996). The contextual interference effect in parameter modifications of the same generalized motor program. Research Quarterly for Exercise and Sport, 67(1), 5

Shea, C. H.; Kohl, R.; & Indermill, C. (1990). Contextual interference: contributions of practice. Acta Psychologica, 73, 145-157.

Sherwood, D. E. (1996). The benefits of random variable practice for spatial accuracy and error detection in a rapid aiming task. Research Quarterly for Exercise and Sport, 67(1), 35-43.

Toussaint, H. M., van Baar, C. E., van Langen, P. P, de Looze, M. P., & van Dieen, J. H. (1992). Coordination of the leg muscles in backlift and leglift. Journal of Biomechanics, 25(11), 1279-1289.

Scholz, J. P. (1993). Low back injury and manual lifting: review and new perspective. Physical Therapy Practice, 1(3), 20-31.

Scholz, J. P., Millford, J. P., & McMillan, A. G. (1995). Neuromuscular coordination of squat lifting I: effect of load magnitude. Physical Therapy, 75(2), 119-132.

van Dieen, J. H., Hoozemans, M.J.M., & Toussaint, H. M. (1999). Stoop or squat: a review of biomechanical studies on lifting technique. Clinical Biomechanics, 14, 685-696.

Wegman, E. (1999). Contextual interference effects on the acquisition and retention of fundamental motor skills. Perceptual and Motor Skills, 88, 182-187.

Wrisberg, C. A., & Liu, Z. (1991). The effect of contextual variety on the practice, retention, and transfer of an applied motor skill. Research Quarterly for Exercise and Sport, 62(4), 406-412.

Appendix A

Flyer

STUDENT, FACULTY, COMMUNITY

VOLUNTEERS ARE
INVITED
TO PARTICIPATE IN A RESEARCH STUDY

AT
SETON HALL UNIVERSITY
SOUTH ORANGE, NJ

This research will examine how lifting practice
effects the coordination of the trunk and lower limb.

Needed: Healthy males and females 20-40 years old

- Participants should have no history of neurological or orthopedic impairments.
- Data collection should take no longer than 45 minutes to 1 hour
- Participation requires 2 separate sessions 7 days apart
- Participants are required to wear shorts and t-shirts
- All information will be confidential
- Individual performance will be shared with each participant upon completion of the study

FOR MORE INFORMATION OR TO ANSWER ANY QUESTIONS
PLEASE CALL OR EMAIL:

Beth Norris, MS, PT
Doctoral Candidate, School of Graduate Medical Education
Seton Hall University
973-971-0012
bnorris01@aol.com

Appendix B

Consent Form

The Effect of Practice Under Conditions of Contextual Interference
on the Interjoint Coordination of Squat Lifting

Informed Consent

Purpose of Research
I have been informed that the purpose of this study will be to assess how 3 different practice methods affect the coordination of the trunk and lower limb during squat lifting. This study may help physical therapists better design treatment programs to best train an individual to utilize a squat technique when lifting.

Procedure
I am aware that I will be examined, asked a series of questions and touched about the shoulders, the low back, and on the side of the right leg by a the investigator. The testing will be conducted on two separate days, 7 days apart. Each session will last 45 minutes to 1 hour. There will be plastic infra-red markers attached to my skin that will send signals to a camera to locate the position in space of the markers in relation to each other. I understand that the camera used will not be able to produce any pictures as a video camera could and that I will be given verbal instructions for exactly what I need to do. I also understand that I will undergo this testing on two separate occasions, 7 days apart, and that all testing will take place in the Functional Human Performance Lab, Duffy Hall, room 71, Seton Hall University.

Risk and Discomfort
I understand that the examiner, a female physical therapist, will be touching me on the right shoulder, the low back, and the right hip, knee, ankle and foot to determine the best place to place the infra-red markers. I may experience some muscle tiredness during the testing and practice. I also understand that muscle soreness may persist for 24-48 hours after the testing.

Benefits
I understand that my participation in the study will have no direct benefit to me other than the potential benefits from practicing lifting loads of different weights. The major potential benefit will be determining if different practice methods effect the coordination of the lower limb (legs) and trunk during squat lifting.

Confidentiality
I understand that medical information produced by this study will be stored in the investigator's research files and identified only by a code number. The code key connecting name to file number will be kept in a separate secure place. If the data are used for publication in the medical literature or for teaching purposes, no names will be used and the anonymity and confidentiality of all the participants will be maintained.

Request for More Information
I understand that I may ask more questions about the study at any time. Beth Norris is available at 973-971-0012 to answer any questions or concerns. I understand that I will be informed of any significant new findings discovered during the course of this study which might influence my continued participation.

If during the study or at a later time, I wish to discuss my participation in or concerns regarding this study with a person not directly involved, I am aware that Genevieve Pinto-Zipp, laboratory director, is available to speak with me at 973-275-2457. A copy of this consent form will be given to me to keep for careful reading.

Refusal or Withdrawal of Participation
I understand that my participation is voluntary and that I may refuse to participate or may withdraw consent and discontinue participation in the study at any time without prejudice to my present or future involvement with Seton Hall University. I also understand that Beth Norris may terminate my participation in this study at any time after she has explained the reasons for doing so.

Injury Statement
The Department of Health and Human Services requires that you be advised as to the availability of medical treatment if a physical injury should result from research procedures. No special medical arrangements have been made regarding your participation in this project. If you are a registered student at SHU, you are eligible to receive medical treatment at the University Health Service. If you are not a registered student at the University, immediate medical treatment is available at usual and customary fees at the local community hospital.

In the event you believe that you have suffered any injury as a result of the participation in the research program, please contact the chairperson of SHU IRB at 973-275-2974, who will review that matter with you, and identify any other resources that may be available to you.

I have explained to ___________________________ the purpose of the research, the procedures required, and the possible risks and benefits to the best of my ability.

_______________________ _______________________

Investigator Date
Beth Norris, MS, PT
Graduate Student
School of Graduate Medical Education

Appendix C

Subject Instructions

Subject ______________________________
Date/time of Day 1 __________________________
Return Date/time for Day 7_____________________

Instructions:
Thank you for your participation in this research study. Please adhere to the following instructions until you return for the second day of testing.

1. Continue normal daily activities.
2. Do not participate in weight training exercises involving squat lifting.
3. Do not perform lifting practice.

If you have any questions, please contact Beth Norris at 973-971-0012 or email address:
Bnorris01@aol.com

Sincerely,

Beth Norris

Appendix D

Experimental Design

Day 1

- MDLC
- Acquisition
  - Record first 9 trials
  - Continue practice 27 trials
- Rest 15 minutes
- Retention
  - Record 9 trials

Blocked Day 1

ANALYSIS ACQUISITION	30 30 30 45 45 45 60 60 60
PRACTICE ACQUISITION	30 30 30 30 30 30 30 30 30 45 45 45 45 45 45 45 45 45 60 60 60 60 60 60 60 60 60
RETENTION	30 30 30 45 45 45 60 60 60

Random Day 1

ANALYSIS ACQUISITION	30 45 60 45 60 30 60 45 30
PRACTICE ACQUISITION	45 60 30 60 45 30 45 30 60 30 60 45 60 30 45 30 45 60 60 30 45 45 60 30 45 30 60
RETENTION	45 40 60 60 45 30 30 45 60

Day 7

- Retention 2
- Rest 5 minutes
- Transfer

Blocked Day 7

RETENTION 2	TRANSFER
30 30 30 45 45 45 60 60 60	15 15 15 75 75 75

Random Day 7

RETENTION 2	TRANSFER
30 45 60 45 60 30 60 30 45	15 74 15 75 15 75

Appendix E

Tables of Means and Standard Deviations for All Dependent Variables

Table E5

Mean Acquisition Starting Posture (degrees of flexion)

For Blocked and Random Practice Conditions

Practice	Load			
Condition	30%	45%	60%	Overall Mean
Blocked				
M	6.99	8.95	13.51	9.82
SE	7.78	7.45	4.63	7.41
Random				
M	7.61	7.87	7.61	7.70
SE	7.78	7.45	4.63	7.41
Overall Mean				
M	7.30	8.41	10.56	
SE	5.50	5.27	5.39	

Table E6

Mean Acquisition Midpoint difference in Blocked and Random Practice Conditions

Practice Condition	Load 30%	45%	60%	Overall Mean
Blocked				
M	.093	.065	.064	.074
SE	.032	.060	.028	.037
Random				
M	.042	.004	.072	.040
SE	.032	.060	.028	.037
Overall Mean				
M	.067	.035	.068	
SE	.023	.042	.020	

Table E7

Mean Acquisition Index of Coordination in Blocked and Random Practice Conditions

Practice Condition	Load 30%	45%	60%	Overall Mean
Blocked				
M	.223	-.072	-.011	.046
SE	.311	.348	.347	.191
Random				
M	.319	.092	-.298	.038
SE	.311	.348	.346	.191
Overall Mean				
M	.271	.010	-.155	
SE	.220	.246	.246	

Table E8

Mean Acquisition Lift Duration in Blocked and Random Practice Conditions

Practice Condition	Load 30%	45%	60%	Overall Mean
Blocked				
M	1.445	1.292	1.286	1.341
SE	.121	.107	.125	.110
Random				
M	1.308	1.378	1.420	1.369
SE	.121	.107	.125	.110
Overall Mean				
M	1.377	1.335	1.353	
SE	.086	.076	.089	

Table E9

Mean Retention Midpoint Difference In Blocked and Random Conditions

Practice	Retention Day 1 Load			Retention Day 7 Load			Overall
Condition	30%	45%	60%	30%	45%	60%	Mean
Blocked							
M	.0520	.0692	.0912	.0610	.0968	.0972	.0779
SE	.029	.069	.028	.025	.023	.035	.031
Random							
M	.0424	.0122	.0836	.0412	.0642	.0970	.0568
SE	.029	.069	.028	.025	.023	.035	.031
Overall							
Mean							
M	.0472	.0407	.0874	.0511	.0805	.0971	
SE	.020	.049	.020	.018	.016	.025	

Table E10

Mean Retention Starting Posture In Blocked and Random Conditions

Practice	Retention Day 1 Load			Retention Day 7 Load			Overall
Condition	30%	45%	60%	30%	45%	60%	Mean
Blocked							
M	9.240	5.660	9.867	9.594	10.620	9.206	9.031
SE	7.546	8.705	7.685	8.792	8.539	7.934	8.033
Random							
M	6.368	8.364	4.468	9.054	9.340	9.778	7.895
SE	7.546	8.705	7.685	8.792	8.539	7.934	8.033
Overall							
Mean							
M	7.804	7.013	7.167	9.324	9.980	9.492	
SE	5.336	6.156	5.434	6.217	6.038	5.610	

Table E11

Mean Retention Index of Coordination For Blocked and Random Practice Conditions

Practice	Retention Day 1 Load			Retention Day 7 Load			Overall
Condition	30%	45%	60%	30%	45%	60%	Mean
Blocked							
M	-.013	-.536	.147	.006	-.162	.042	-.086
SE	.368	.300	.330	.291	.310	.390	.142
Random							
M	-.342	.143	.146	-.087	.411	.042	.052
SE	.368	.300	.330	.291	.309	.390	.142
Overall Mean							
M	-.178	-.196	.146	-.040	.124	.042	
SE	.260	.212	.234	.206	.219	.276	

Table E12

Mean Retention Lift Duration For Blocked and Random Practice Conditions

Practice	Retention Day 1 Load			Retention Day 7 Load			Overall
Condition	30%	45%	60%	30%	45%	60%	Mean
Blocked							
M	1.230	1.268	1.240	1.116	1.236	1.214	1.217
SE	.106	.109	.100	.075	.098	.096	.072
Random							
M	1.188	1.178	1.358	1.176	1.254	1.378	1.255
SE	.106	.109	.100	.075	.098	.096	.060
Overall Mean							
M	1.209	1.223	1.299	1.146	1.245	1.296	
SE	.075	.077	.070	.053	.070	.068	

Table E13

Mean Transfer Starting Posture

For Blocked and Random Practice Conditions

Practice	Load		
Condition	15%	75%	Overall Mean
Blocked			
M	8.353	12.142	10.248
SE	4.665	4.560	7.939
Random			
M	4.833	5.586	5.210
SE	4.665	4.560	7.939
Overall Mean			
M	6.594	8.864	
SE	5.778	5.555	

Table E14

Mean Transfer Midpoint Difference For Blocked and Random Practice Conditions

Practice	Load		
Condition	15%	75%	Overall Mean
Blocked			
M	.0310	.0448	.0379
SE	.022	.046	.031
Random			
M	.0178	.132	.075
SE	.022	.046	.031
Overall Mean			
M	.0244	.0885	
SE	.016	.033	

Table E15

Mean Transfer Index of Coordination For Blocked and Random Practice Conditions

Practice Condition	Load 15%	75%	Overall Mean
Blocked			
M	.767	-.406	.180
SE	.174	.349	.185
Random			
M	.668	-.093	.288
SE	.174	.349	.185
Overall Mean			
M	.718	-.250	
SE	.123	.247	

Table E16

Mean Transfer Lift Duration For Blocked and Random Practice Conditions

Practice	Load		
Condition	15%	75%	Overall Mean
Blocked			
M	1.078	1.240	1.159
SE	.096	.108	.093
Random			
M	1.142	1.600	1.371
SE	.096	.108	.093
Overall Mean			
M	1.110	1.420	
SE	.068	.077	

Appendix F

Analysis of Variance Summary Tables

Table F17

Analysis of Variance for Acquisition Starting Posture

Source	df	MS	F	p
Between Subjects				
Practice Condition	1	33.772	.014[a]	.749
Error (condition)	8	822.728		
Within Subjects				
Load	2	27.481	1.124[b]	.349
Error (load)	16	24.442		
Condition x Load	2	28.581	1.169	.336

[a]Table F (.05) (1, 8) = 5.32

[b]Table F (.05) (2, 16,) = 3.63

Table F18

Analysis of Variance for Retention Starting Posture

Source	df	MS	F	p
Between Subjects				
Practice Condition	1	19.357	.010[a]	.923
Error (condition)	8	1935.713		
Within Subjects				
Load	2	.291	.019[b]	.981
Error (load)	16	15.344		
Time	1	77.339	2.873[a]	.129
Error (time)	8	26.921		
Condition x Load	2	13.418	.874[b]	.436
Time x Load	2	2.628	.167[b]	.847
Error	16	15.709		
Condition x Time	1	7.776	.289[a]	.606
Condition x Load x Time	2	31.697	2.018[b]	.165

[a]Table F (.05) (1, 8) = 5.32

[b]Table F (.05) (2,16,) = 3.63

Table F19

Analysis of Variance for Transfer Starting Posture

Source	df	MS	F	p
Between Subjects				
Practice Condition	1	126.907	.201[a]	.666
Error (condition)	18	630.284		
Within Subjects				
Load	1	25.765	2.115[a]	.184
Error (load)	18	12.184		
Condition x Load	1	11.552	.946[a]	.359

[a]Table F (.05) (1, 28) = 4.20

Table F20

Analysis of Variance for Acquisition Midpoint Difference

Source	df	MS	F	p
Condition	1	.009	.453	.528
Error (condition)	8	.020		
Load	2	.004	1.087	.361
Error (load)	16	.003		
Condition x Load	2	.003	1.031	.379

Table F (.05) (1, 8) = 5.32

Table F (.05) (2,16) = 3.63

Table F21

Analysis of Variance for Retention Midpoint Difference

Source	df	MS	F	p
Condition	1	.0067	.226	.647
Error (condition)	8	.0296		
Load	2	.0100	3.442	.057
Error (load)	16	.0029		
Time	1	.0048	1.014	.343
Error (time)	8	.0047		
Condition x Load	2	.0005	.776	.477
Time x Load	2	.0019	.927	.416
Error (time x load)	16	.0020		
Condition x Time	1	.0022	.041	.844
Condition x Load x Time	2	.04	.187	.831

Table F (1, 8) = 5.32
Table F (2,16) = 3.63

Table F22

Analysis of Variance for Transfer Midpoint Difference

Source	df	MS	F	p
Condition	1	.021	.696	.428
Error (condition)	8	.010		
Load	1	.02	6.602	.033[a]
Error (load)	8	.003		
Condition x Load	1	.026	4.605	.079

[a]Table F (.05) (1, 28) = 4.20

Table F23

Analysis of Variance for Acquisition Index of Coordination

Source	df	MS	F	p
Condition	1	.060	.001	.974
Error (condition)	8	.549		
Load	2	.461	.805	.464
Error (load)	16	.573		
Condition x Load	2	.148	.249	.775

Table F (.05) (1, 8) = 5.32

Table F (.05) (2,16) = 3.63

Table F24

Analysis of Variance for Retention Index of Coordination

Source	df	MS	F	p
Condition	1	.283	.464	.515
Error (condition)	8	.609		
Load	2	.211	.726	.499
Error (load)	16	.291		
Time	1	.212	.316	.589
Error (time)	8	.699		
Condition x Load	2	.940	3.235	.066
Time x Load	2	.230	.311	.737
Error	16	.737		
Condition x Time	1	.007	.010	.923
Condition x Load x Time	2	.039	.054	.948

Table F (.05) (1,8) = 5.32

Table F (.05) (2,16) = 3.63

Table F25

Analysis of Variance for Transfer Index of Coordination

Source	df	MS	F	p
Condition	1	.057	.168	.693
Error (condition)	8	.341		
Load	1	4.677	11.161	.010*
Error (load)	8	.419		
Condition x Load	1	.213	.509	.496

*Table F (.05) (1, 8) = 5.32

Table F26

Analysis of Variance for Acquisition Lift Duration

Source	df	MS	F	p
Condition	1	.006	.031[a]	.865
Error (condition)	8	.182		
Load	2	.004	.320[b]	.731
Error (load)	16	.014		
Condition x Load	2	.053	3.792	.045*

Table F (.05) (1, 8) = 5.32

Table F (.05) (2,16) = 3.63

* $p < .05$

Table F27

Analysis of Variance for Retention Lift Duration

Source	df	MS	F	p
Condition	1	.022	.105	.754
Error (condition)	8	.206		
Load	2	.072	10.764	.001[a]
Error (load)	16	.007		
Time	1	.003	.059	.814
Error (time)	8	.055		
Condition x Load	2	.042	6.319	.009[b]
Time x Load	2	.009	1.397	.276
Error	16	.007		
Condition x Time	1	.027	.498	.500
Condition x Load x Time	2	.001	.214	.810

[a]Table F (.05) (1,8) = 5.32

[b]Table F (.05) (2,16) = 3.63

Table F28

Analysis of Variance for Transfer Lift Duration

Source	df	MS	F	p
Condition	1	.225	2.594	.146
Error (condition)	8	.087		
Load	1	.480	26.885	.001[a]
Error (load)	8	.018		
Condition x Load	1	.110	6.128	.038[a]

[a]Table F (.05) (1, 8) = 5.32